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THE JOURNAL OF WILDLIFE MANAGEMENT

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WATER DEVELOPMENT FOR DESERT BIGHORN SHEEP

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The primary purpose of this paper is to describe the various types of water installations that have been built for the benefit of desert bighorn sheep (*Ovis canadensis*) on the Desert Game Range of southern Nevada and the Kofa and Cabeza Prieta game ranges of southwestern Arizona.

These installations, or developments as they are subsequently called in this report, have been constructed over a period of twenty years. The work has been done by Civilian Conservation Corps personnel, temporary labor hired for the purpose, and regular Fish and Wildlife Service personnel. Actual costs and engineering details are not included in this paper. The Engineering Branch of the Fish and Wildlife Service drew up the plans for the majority of the structures and was freely consulted in connection with construction details.

The need for desert bighorn refuges and development of their water for desert bighorn has long been recognized (Nichol, 1937). The principal Federal areas that were created as a result of this need were the Desert Game Range of southern Nevada, the Kofa and Cabeza Prieta game ranges of southwestern Arizona, and the San Andres National Wildlife Refuge in southern New Mexico. The game on these areas is managed by the U.S. Fish and Wildlife Service of the Department of the Interior. In addition, areas have been set up by other Federal agencies and by the various state game and fish departments for the benefit of desert game. One of these, where early water development for bighorns was accomplished, was the Hatchet Mountain Management Area administered by the New Mexico Department of Game and Fish.

HISTORY OF WATER USE AND STORAGE

In the days before the white man invaded the country, game could travel to the principal rivers of the Southwest when water failed in the mountains. Many of these larger river bottoms are now inhabited by man and no longer are available. Elsewhere, irrigation dams have been built, and the water supply of game animals has been drastically decreased or cut off for many miles below the dams (Nichol, *ibid.*).

The Kofa and Cabeza Prieta game ranges are a case in point. They drain to the Colorado and Gila rivers. The bottom lands of these rivers, because of extensive farming, are no longer available to big game from these areas. As a result, this game now must depend upon waters found in the dry desert ranges.

Some of the most extreme desert conditions found in the United States exist in southwestern Arizona. The summers are long and hot, with maximum recorded temperatures of 127°F. The annual rainfall averages approximately 3½ inches. In some years, much less is received; in 1953, 0.31 inch of rain was recorded at the Yuma Station of the U.S. Weather Bureau. The evaporation of water from an open surface in this Sonoran region is approximately 11 to 12 feet per year.

Game trails and Indian routes still can be seen leading to usually isolated and sometimes intermittent waters on the desert. Early Indian petroglyphs in some areas give information as to where springs can be found or where water can be obtained by digging.

The first attempts by white men to create

structures for storing rain water in the desert of this region were probably devised by the early prospectors. Soon after a likely display of "pay dirt" was located, the prospector began construction of a cistern as close to camp as possible. The first storage basin may have been little more than a roof placed over a pothole or natural tank that collected rain water from floods. Without such natural water, the prospector would excavate an area at the base of a small hill, line it with concrete, and construct an apron

FIG. 1. An early spring development on the Desert Game Range. The collecting basins prevent water wastage and prolong the use of this weak intermittent spring.

to catch rain water and direct it into the catchment. Cisterns of this kind can still be found at old desert diggings.

After the miner became auto-borne, and increased mobility made possible the hauling of water to his claim, the old "prospector's well" was largely discarded and forgotten. Recently, however, the idea has been revived. A few changes have been made, and it has been launched as an effective tool for game-bird managers under the name of "gallinaceous guzzler" (Glading, 1943 and 1947).

As livestock began to move into the desert valleys and mountains, ranchers sought ways of keeping animals on water-deficient areas affording good forage. Reservoirs were excavated on flood plains, and dams were built in canyons to catch and store the flood waters of local thunderstorms. In most cases, little effort was exerted toward creating facilities to keep the water cool, prevent pollution, or retard evaporation.

During the 1930's and the period of the Civilian Conservation Corps, several types of structures to develop water were constructed on the Kofa Game Range. For the past several years, additional structures have been built on this refuge and the nearby Cabeza Prieta Game Range. Water-development work began about 10 years later on the Desert Game Range of southern Nevada. Through this start and work done elsewhere, development of waters on desert ranges has been shown to provide a practical method of increasing the numbers of bighorn sheep.

WATER ESSENTIAL TO RESTORATION

As has been pointed out by Barclay (1947) and others, much favorable habitat for bighorn sheep is left unused at certain seasons because of the scarcity or absence of water. The development of water resources doubtless lowers the disease and predation potential for the sheep and leads to more uniform range utilization.

Water is also an important factor in bighorn lambing country. In dry years, ewes require more water during lambing because of the scarcity of green feed. Ewes, because of their limited mobility at such times, will entrench themselves near water. This may cause local overuse. When the watering places of favored lambing grounds in the Sheep Range of southern Nevada become dry, the ewes leave and crowd into less favorable but better watered areas.

In some areas livestock and feral burros compete with the bighorns. A cow or horse will drink several times the amount of water needed by a bighorn. A band of 10 horses on the Desert Game Range completely utilized a small spring that had supplied 30 to 40 bighorn before the intrusion of the horses. On the Kofa Game Range some natural tanks and water structures have dried by midsummer because of use by livestock, burros, deer, and bighorns. It is therefore important that consideration be given to the development of game water in areas not used by domestic stock. Feral burros that compete with bighorns for water must be eliminated or reduced to very low numbers (Halloran, 1949).

In areas of extreme water scarcity where competition by livestock is excessive, the problem may be solved by fencing off the spring or seep from the intruding animals, which thereupon promptly leave the area. Such a problem was solved on the Desert Game Range by piping the limited flow of water into a storage tank at the base of a ledge. The ledge was too steep for horses, but bighorns could climb up and down it with ease. The other three sides of the area were fenced, about 10 feet back from the tank, with strands of barbed wire one foot apart. However, horses pawed the wire with their hooves until the strands broke and they were able to reach the water. Barrier arms were then installed on each post, extending outward from the fence for a distance of 3 feet and about as high off the ground as the upper leg and chest of an average-sized horse. Two strands of heavy barbed wire were placed on the apex of the barrier arm, and these strands tended to deter any animal seeking to break down the fence. The fence was completed by stretching barbed wire on fence posts above the barrier arms and by placing heavy-gauge

hog wire on the lower 3 feet of the posts.

At water holes and springs where topography does not permit use of a cliff or ledge as the access route for the sheep, some experimentation might be carried on with a barrier-arm-type fence, omitting the hog wire fencing and leaving enough of the lower portion open to permit passage of sheep, yet retard livestock. At the Hart Mountain National Antelope Refuge in Oregon and the Charles Sheldon National Antelope Refuge and Range in northern Nevada, fences have been built with the lowest strand high enough to permit antelope (*Antilocapra americana*) to pass under, yet low enough to prevent livestock penetration.

SELECTION OF SITES

The effectiveness of a water structure in the desert is governed largely by its location and intended purpose. Russo (1956: 83) has well outlined the requirements for bighorn watering structures in desert locations.

In selecting sites for the collection of arroyo-running rain water, it is important that the local "rain shadows" be known. These are localized spots, present in southwestern desert country, where less rain falls than on nearby areas. One reason for the existence of these "shadows" is that mountains rising abruptly, say, to 1,500 feet above the desert floor, create air currents, which in turn modify storm cloud distribution. Talks with old timers or U.S. Weather Bureau people will often reveal data concerning the location of rain-deficient sites.

Care should also be used to see that primary developments are not constructed at locations where poaching might become a law-enforcement problem.

NUMBER OF DEVELOPMENTS NEEDED

Stored desert water is rarely abundant, and the bighorn manager should plan to improve or create watering places so that water is available in critical seasons over the entire habitat within the daily cruising radius of these native sheep. Bighorns, as a general rule, do not water every day and often travel several miles to water. Dependable water every 5 miles in favorable habitat will meet the minimum requirements of this species (Barclay, *op. cit.*). It is advisable, however, in a long-range water-development program, to provide additional water sources at intermediate points to offset the possibility of springs going dry and rain storms by-passing some of the rain-catching structures. A number of small, well-located, dependable developments scattered over several drainages is an effective management technique.

Water-development programs are, through economic necessity, long-range propositions. In laying out a program, the manager should make a careful reconnaissance of his area, mapping all known waters and locating and mapping suitable construction sites. Construction priorities are then established. On the Cabeza Prieta one major development in each principal mountain range was the first order of business.

TYPES OF DEVELOPMENTS

Watering improvements for sheep can be listed under two main classifications: spring developments and rain catchments.

Spring Developments

On the Cabeza Prieta Game Range of almost one million acres, there is only one known permanent spring. When inspected after a prolonged drought, it still flowed to the extent of almost 2 gallons an hour. Refuge workers maintain this spring by keeping it free of debris. No blasting has been done to enlarge the pool, for fear of losing this important sheep and deer watering site.

On the Kofa, there are seven developed springs. Two of these are in low country and are shared with cattle; three are of the strong "wet-season-seep" type but cannot be relied upon in long dry spells. The methods of protecting these waters vary with local conditions.

Some springs have to be protected from cloudbursts (Jones, Flitner, and Gard, 1957). In one case on the Kofa Game Range, where a spring was found in an arroyo bottom, the water was piped in a covered trench to a

water trough on the side of the watercourse, out of reach of cloudburst floods. Large rocks were placed around the spring source, which was then capped with concrete to protect it.

Many springs have to be protected from evaporation. In some cases this has been accomplished by building a reinforced concrete structure over the spring. This also protects from excessive livestock trampling. In other cases a metal sun shade will be sufficient.

In rare cases, a spring can be found in a natural cave accessible to sheep but inaccessible to livestock or burros. This is an ideal situation. Small metal containers, such as discarded oil drums, can be carried into the cave and placed to store the flow. In this way more water is available for more game over a longer period. If spring flow is sufficient, a watering trough can be placed below.

Troughs should be placed to the side of the main watercourse below springs or dams to prevent flood damage. In order to keep the trough from becoming a trap for birds and rodents, a ramp should run to the bottom (Bond, 1947). Troughs below dams can be equipped with a float valve to conserve water.

Well-made, concrete troughs are more suitable for the desert than metal ones. Metal troughs, through heating, raise the water temperature and promote the growth of algae. This can be offset to some extent by placing metal troughs where they are shaded from the direct rays of the sun or by building shades over them. A metal trough is more quickly installed than a concrete one, thereby cutting construction costs, particularly at isolated locations. Air space should be provided under the trough to prevent rusting.

The tops of troughs should be high enough above ground level to prevent animals from knocking debris into the water. All troughs should be inspected and cleared of unwanted plant growth and detritus before the beginning of the critical summer watering season. Cleaning is simplified if a drain is provided.

Rain Catchments

This type of project constitutes a most important kind of development work both from the standpoint of numbers and of the amount of water stored.

Many of these rain-catchment basins, locally called "tanks," are made by improving on what nature has provided. Natural rock water holes exist in many desert watercourses or arroyos. These natural tanks are filled on occasion by the local rains of summer or the more general rains of winter. The various methods of developing new water holes or improving on those provided by nature are described below. If possible, plans for these should be drawn to provide for a water supply that will last at least 12 to 18 months.

Reinforced concrete dams.—It has been found that water-cut canyons offer suitable sites for dams made of concrete. Dams should be firmly keyed to the bedrock on the sides and bottom. Water loss will be prevented if rock formations are checked for cracks and fissures. Rock-sealing is, at times, an important phase of sound construction. Commercial sealers can be quickly applied to both the rock and the dam after completion and are very good insurance.

Generally speaking, these structures are under 40 feet in length and not over 10 or 12 feet high. These rubble-silt retention dams contain one or more capped pipes through their bases. During the first several years after construction, the small ponds formed behind the dams are an excellent source of additional water for game. Gradually, however, this area fills with gravel and sand washed in by local torrential rains (Fig. 2). Flood water soaking into this gravel is stored and protected from excessive evaporation. When the tanks or holes in the impervious rock below the dam become dry, it is then a simple matter to uncap the pipes and refill them from the stored water under the gravel behind the dam. In many cases these natural basins have been deepened by blasting or by tunneling into the solid rock of the arroyo below the dam to create shaded pools. Some of these blasted-out storage tanks pierce hard granite as much

FIG. 2. Reinforced concrete dam with blasted-out storage pool below. Note that floods from cloudbursts have not yet filled the area behind the dam with silt.

as 20 feet and may hold water to a depth of 12 feet.

Underground storage tanks.—After the "gallinaceous guzzler" device with a rain-catching apron and underground storage tank was developed for desert quail, the next logical step was to construct "king-size" guzzlers for deer and sheep (Fig. 3). The California Department of Fish and Game, working with this type, has installed many in the miles-long washes of southeastern California. These have proved successful, especially for desert mule deer (*Odocoileus hemionus*), but can be used in sheep country for bighorns where suitable sites are available. A variation of this watering device has been used in the badly fractured ranges of the Cabeza Prieta, where water-holding rocks are difficult to find. Storage tanks have been blasted into the sides of arroyos. Semicircular walls of boulders have been built at the entrances, protecting the upstream sides from debris, but allowing part of the arroyo flood waters to pass through these porous walls and fill the basins. It is sometimes necessary to seal the shaded storage pool with concrete or other sealers to prevent seepage through rock fractures. The slopes into these artificial caves should be roughened, if necessary, to provide solid footing for game. In southern Arizona the water storage depth should be at least 12 feet to insure a dependable supply.

Concrete or metal catchments can be provided in old, abandoned mine tunnels that sometimes drip cool ground water through the longest droughts.

Earthen dams.—A site for an earthen dam of benefit primarily to sheep is seldom found. Under certain conditions, however, larger earthen dams are important. An example of this type is found on the Kofa. During the days of the Civilian Conservation Corps, the Bureau of Land Management (formerly the Grazing Service) constructed several earthen tanks in the wider washes to catch the water as it flowed out of the mountains and onto the sandy and rocky lands between the ranges. These tanks are used by cattle and also by game—especially deer. In some cases, when the waters farther back are dry, sheep will be found at these charcos.

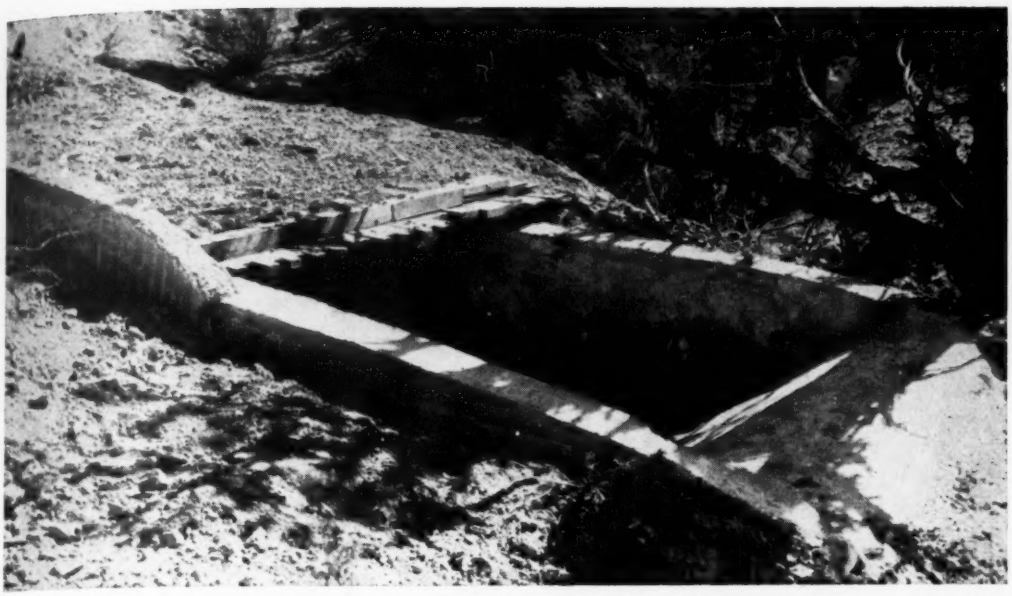

FIG. 3. An underground storage tank or "king-size" guzzler. Bighorn sheep soon learn to enter these without hesitation. On the Kofa Range, sheep enter a mine tunnel and drink at an underground pool 200 feet from the entrance.

The rainfall on the desert is spotty. One range of mountains may receive a local shower, while a nearby range does not receive a drop. At times like these, sheep may move from a dry range to the one that received rainfall. On these range-changing treks, sheep many times utilize the water at stock tanks located on desert plains several miles from the base of the mountains.

Miscellaneous water.—The cattlemen who use the Kofa Game Range have also dug a number of shallow mountain wells and installed windmills. Both sheep and deer have been known to water at these developments.

For over 75 years there has been mining activity in the mountains now included in the Kofa Game Range. Some of these mines are semiactive today and, to prevent at least two such mines from flooding, caretakers pump water and make it available for game. Water from one of these mines in the Castle Dome Mountains supports a large herd of mule deer.

In addition, there are many natural, seasonal springs or seeps and numerous shallow, "wet-season," natural rock tanks. These are of importance, as they allow better game distribution during parts of the year when the water situation is less critical.

When the Fish and Wildlife Service first established the Kofa Game Range in 1939, several natural rock tanks were found that had slippery, nearly vertical sides. As the water became low, deer and sheep tried to reach it, slipped in and drowned. Several such death traps were roughened by blasting and no longer take a toll of desert game.

REACTION OF BIGHORNS TO WATER DEVELOPMENTS

Bighorn sheep make the transition from seep or spring to tank or trough with little evidence of reluctance. Their tracks can be seen around tanks and troughs soon after completion. At Rye Patch Spring on the Desert Game Range, a bighorn drank out of a new trough 2 hours after installation. At Quartz Spring, at the north end of the Pintwater Range of southern Nevada, the flow from the spring was so limited that an underground storage tank was installed to collect water. The sheep soon became accustomed to using a ramp leading from

FIG. 4. Budweiser Spring on the Kofa. This intermittent spring in an arroyo is protected from the sun and arroyo debris by a concrete cover.

ground level to water. At one place in the Kofa Mountains, bighorns enter a long, dark mine tunnel to water at the far end.

It is inadvisable to pipe water very far out of sight of the original watering location. At Cabin Springs, in the Sheep Range, water was piped 680 feet to a trapping corral. This new location was out of sight of the spring head where the animals were accustomed to water. During the first summer, the sheep did not water at the new location, but milled around the fence that enclosed the head of the spring. By the second summer some of the sheep had found the new location, and led others to water.

Bighorn sheep will enter enclosures if there is some incentive for them to enter. They have been trapped in corral-type traps built around a water trough. They will climb up and down cliffs to water in narrow draws fenced against unauthorized stock.

SUMMARY

On refuges for bighorn sheep in the Southwest, watering devices have materially improved range conditions for this species. Dependable water is needed every 5 miles in favorable habitat. Springs are kept free of debris and are protected from cloudbursts, livestock, and evaporation by covered troughs in safe locations. Rain catchments have been extremely useful, especially those providing water that will last 12 to 18 months. Reinforced concrete dams are used in water-cut canyons; underground storage tanks have been blasted into the sides of arroyos. Earthen dams are useful under special conditions. These developments are readily accepted by the sheep, but care must be taken (1) to avoid piping water to troughs that are too far away from traditionally used sites, (2) to locate installations

with due respect to local "rain shadows" and poaching possibilities, (3) to use sealers on rock and concrete, and (4), under certain conditions, to provide ramps for the animals' use.

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FOOD HABITS OF THE MOURNING DOVE IN MISSOURI[1]

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This investigation was conducted to learn the principal foods used by mourning doves (*Zenaidura macroura*) in Missouri, as a basis for management. The study period included the spring, summer, and fall months when doves were in greatest abundance.

TECHNIQUES OF STUDY

Dove crops, used as a basis for this report, were supplied by cooperating hunters, employees of the Missouri Conservation Commission, and students of the Missouri Cooperative Wildlife Research Unit.

The first 174 samples were collected as opportunity permitted from 1946 to 1950. Virtually all were obtained during the September hunting seasons. Organization of a more complete life-history study of the mourning dove during fiscal year July 1951–52 (Wight, 1952) presented an opportunity to obtain additional materials for food-habits study. Requests were sent to cooperating hunters throughout the state to send in crops from birds they killed during the 1951 hunting season. A total of 381 crops which contained food were received. Additional collections, beginning in May 1952, provided information for the spring and summer months. An intensified effort again was made during the fall of 1952 to obtain crops from hunters, and 1,017 crops were received. Spring and summer collecting continued during 1953–54 to supplement data previously obtained and yielded 418 samples. No special effort was made to add to the September (hunting-season) data. The

[1] A contribution from the Federal-Aid to Wildlife Restoration Program, Surveys and Investigations Projects, Missouri 13-R.

[2] I wish to acknowledge the cooperation of many individual hunters, Conservation Commission personnel, and students of the University of Missouri who assisted with the collection of materials for this investigation. Special thanks are due Howard M. Wight, biologist, Conservation Commission; David C. McGlauchlin, Thomas W. Martin, and Howard T. Lovrien, students, Missouri Cooperative Wildlife Research Unit, for their extensive help; and A. C. Martin, biologist, U.S. Fish and Wildlife Service, for the identification of difficult food items.

remaining 10 crops of the 2,000 analyzed for this report were collected during April 1954.

Materials for preserving and mailing crops were furnished by the Conservation Commission to each cooperating hunter, upon request. Materials included: 3-inch × 5-inch coin envelopes printed to show date of collection, county hunted, and collector's name. Manila self-addressed business-reply envelopes, 7 inches × 10 inches, were supplied for mailing the samples.

Samples were analyzed by standard food-habits procedures as promptly as possible to prevent spoilage and to facilitate the identification of "dove milk."

Plants were classified according to *Gray's Manual of Botany*, eighth edition (Fernald, 1950), except for a few common names of plants.

REVIEW OF LITERATURE

A review of the literature reveals a general similarity of dove feeding habits throughout the bird's range, yet indicates the fallacy of applying data from one region to another. Investigators agree that almost the entire dove diet comes from plants. Percentages of the principal foods, however, showed marked variation between seasons, years, or regions of the country where the various studies were conducted.

Dutcher (1903), one of the first to report on mourning dove food habits, stated that in 237 stomachs examined cereal grains constituted 32 per cent of the total food, and wheat was the favorite. Knappen (1938) reported that, in the Southeastern States, corn was the most important single item of food for 219 doves. Bristlegrass and Egyptian grass were next in importance. Rosene (1939) found that corn was the principal food of 287 doves in Alabama and that wheat was regularly eaten during the summer months. Pearson and Webb (1942) also found corn to be the principal spring food in the diet of 163 Alabama doves. Leopold (1943) pointed out the annual differences in feeding habits of doves in Missouri. They ate mostly foxtail grass in September 1939, but mostly wheat in September of other years. Another midwestern study was that of McClure (1943), who found that 157 nestling doves were fed principally hemp, wheat, corn, and foxtail grasses. Martin, Zim, and Nelson (1951:111–112) recorded the principal dove foods of the United States, by region. Cummings and Quay (1953) found that the principal foods of 553 doves in North Carolina were crab-grass, corn, foxtail, paspalum, and wheat. Jackson (1941) reported that in Texas the foods of 201 doves collected during August consisted of more than 85 per cent grasses and nearly 10 per cent spurges. Other studies involving fewer samples were: Jennings (1941); Dahlgren (1952); and Cowan (1952).

RESULTS

Data were derived from analyses of dove crops collected in 55 of Missouri's 114 counties and were well distributed throughout the state. The principal foods of doves for each month, April through October, are shown in Table 1. All the plant foods consisted of seeds. Data from small samples for April and October were included for what significance they may have.

A list of important foods found in 1,959 dove crops collected from May through September comprises Table 2. Percentages in Table 2 are adjusted averages for the five-months' period, computed as arithmetic means of the monthly percentages of important items. The adjusted data are based upon the premise that sufficient information was obtained for each of the five months; April and October data were omitted as being insufficient. By leveling seasonal variations in food consumption and sample size, averages for the various items more truly represent the state-wide, year-round feeding of doves in Missouri.

Davison (1940) concluded that for quail and doves more than 50 crops, preferably 100 to 200, are needed to determine the importance of foods in a single locality. Korschgen (1948) found that the majority of principal quail foods of a region were identified in the first 100 crops, but a larger number of samples provided greater accuracy. On the same basis, a similar num-

TABLE 1.—PRINCIPAL FOODS OF 2,000 MOURNING DOVES IN MISSOURI, BY MONTH

	Percentages by Occurrence[1] and Volume													
Month	April		May		June		July		August		September		October	
No. Crops Examined	22		93		122		148		227		1,369		19	
FOOD ITEM	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.
Corn	91.0	78.9	84.9	77.5	67.2	51.4	27.7	9.0	39.6	15.5	41.5	21.4	5.3	0.1
Wheat	9.1	0.3	10.8	1.0	36.9	22.9	91.2	78.4	66.1	46.5	36.5	21.2	10.5	0.3
Yellow foxtail	36.4	1.5	48.4	2.4	50.0	4.3	14.9	0.2	47.1	19.5	74.9	32.0	15.8	0.5
Giant foxtail	45.5	2.2	20.4	2.1	13.9	1.2	6.1	0.9	15.4	4.0	15.9	3.9	—	—
Small wild bean	22.7	1.7	14.0	1.8	31.1	2.0	32.4	2.4	36.6	2.3	20.4	0.6	—	—
Sand croton	—	—	1.1	0.2	—	—	2.7	0.1	2.2	0.1	24.5	6.6	5.3	0.1
Common ragweed	50.0	2.4	30.1	1.2	36.9	3.7	23.0	0.8	18.5	0.8	11.9	0.5	10.5	tr.
Hogwort	27.3	6.9	3.2	1.7	4.9	0.5	8.8	0.6	13.2	2.4	13.0	1.4	5.3	0.3
Cane	4.5	1.2	3.2	2.6	1.6	0.6	1.4	tr.	0.9	0.7	1.7	0.3	31.6	39.8
Painted-leaf	4.5	0.4	4.3	1.3	2.5	0.4	—	—	3.5	1.4	7.9	0.6	—	—
Cranesbill	—	—	—	—	18.0	2.7	6.8	0.4	6.2	tr.	3.3	tr.	—	—
Milk-purslane	—	—	—	—	0.8	tr.	27.0	1.1	27.8	1.4	18.0	0.5	—	—
Eyebane	—	—	—	—	2.5	tr.	0.7	tr.	5.7	0.3	24.5	2.7	—	—
Total		95.5		91.8		89.7		93.9		94.9		91.7		41.1

[1] The percentages shown have been carried one digit past the decimal place for comparative purposes only.

TABLE 2.—MAJOR FOODS OF DOVES IN MISSOURI, MAY THROUGH SEPTEMBER
(Figures are averages for the period, based upon examination of 1,959 crops)

Food Item[1]	Per Cent by Occ.	Per Cent by Vol.	Food Item[1]	Per Cent by Occ.	Per Cent by Vol.
PLANT FOODS			Pokeweed (*Phytolacca americana*)	4.8	0.2
Corn (*Zea Mays*)	52.1	35.0	Violets (*Viola spp.*)	3.9	0.2
Wheat (*Triticum aestivum*)	48.3	34.0	Fringeleaf paspalum (*Paspalum ciliatifolium*)	15.5	0.2
Yellow foxtail (*Setaria glauca*)	47.1	11.7	Wood-sorrels (*Oxalis* spp.)	12.8	0.2
Giant foxtail (*S. Faberii*)	14.3	2.4	Crab-grass (*Digitaria sanguinalis*)	13.8	0.2
Small wild bean (*Strophostyles leiosperma*)	26.9	1.8	Prickly mallow (*Sida spinosa*)	12.3	0.1
Sand croton (*Croton glandulosus*)	6.1	1.4	Wolf's-milk (*Euphorbia obtusata*)	1.1	0.1
Common ragweed (*Ambrosia artemisiifolia*)	24.1	1.4	Panic-grasses (*Panicum* spp.)	5.9	0.1
Hogwort (*Croton capitatus*)	8.6	1.3	Japanese millet (*Echinochloa frumentacea*)	1.8	0.1
Cane (*Sorgum vulgare*)	1.8	0.8	Tumbleweed (*Amaranthus graecizans*)	2.6	0.1
Painted-leaf (*Euphorbia heterophylla*)	3.4	0.7	Copperleaf (*Acalypha ostryaefolia*)	0.7	0.1
Cranesbill (*Geranium carolinianum*)	6.9	0.6	Great ragweed (*Ambrosia trifida*)	0.6	0.1
Milk-purslane (*Euphorbia supina*)	14.7	0.6	Three-seeded mercury (*Acalypha virginica*)	11.1	0.1
Eyebane (*E. maculata*)	6.7	0.6	Flowering spurge (*Euphorbia corollata*)	0.9	0.1
Timothy (*Phleum pratense*)	12.4	0.6	Corn-gromwell (*Lithospermum arvense*)	0.7	0.1
Fall panic-grass (*Panicum dichotomiflorum*)	35.4	0.5	Rye (*Secale cereale*)	0.6	0.1
Green foxtail (*Setaria viridis*)	8.5	0.4	Old-witch grass (*Panicum capillare*)	5.0	0.1
Pinkweed (*Polygonum pensylvanicum*)	10.6	0.4	Trailing wild bean (*Strophostyles helvola*)	2.5	0.1
Small crab-grass (*Digitaria Ischaemum*)	19.0	0.3	ANIMAL FOODS		
Prairie-tea (*Croton monanthogynus*)	4.4	0.3	Snails, unclassified (Gastropoda)	13.1	0.1
Millet (*Setaria italica*)	1.2	0.3	Pupoid snails (*Gastrocopta armifera*)	5.3	0.1
Cottonwood (*Populus deltoides*)	2.1	0.3	Pupoid snails (*Pupoides marginatus*)	5.4	0.1
Korean lespedeza (*Lespedeza stipulacea*)	23.8	0.2	Insect galls	1.0	0.1
Goose-grass (*Eleusine indica*)	8.6	0.2			

[1] Minor items involved 177 plant and 35 animal foods, each in trace amount. Detailed (multilithed) list available from author on request. Gravel occurred on the average in 28.5 per cent of the crops and represented 0.4 per cent of the average volume.

ber should adequately show the important monthly or seasonal foods.

If previous tests were accurate, it may be assumed that adequate materials were included in this study for all months except April and October. A limited number of doves are resident in Missouri throughout the year, but collecting in early spring and late fall is very difficult because of low populations. The normal build-up of a spring breeding population occurs during May in Missouri, while the major fall migration of our summer residents takes place in August.

Seasonal Foods

The diet of Missouri doves changed considerably from spring to fall, but a few common foods dominated throughout the year. Nonstaple seasonal foods of importance were the exception; a few staples usually comprised the bulk of the diet. The agricultural-plant category used in this report included: corn, wheat, cultivated millet, cane, rye, barley, timothy, oats, buckwheat, and soybeans.

April foods.—In the 22 crops examined, 38 plant and 5 animal foods were identified. This study showed that the dove's entire plant diet during April in Missouri consisted of seeds from plants of the previous year. Corn alone supplied nearly four-fifths (78.9 per cent) of the April foods, by volume. Annual grasses, principally corn, made up 86.1 per cent of the total food, and agricultural plants accounted for 81.3 per cent.

May foods.—In the 93 samples examined, 72 plants and 15 animal foods were identified, but only 12 plant foods made up as much as 1.0 per cent each of the diet. An example of seasonal feeding on nonstaples was the consumption of seeds of cottonwood (*Populus deltoides*) as the seventh most important food during May. Other early-maturing seeds, such as field-pansy (*Viola Kitaibeliana*), buttercup (*Ranunculus abortivus*), and chickweed (*Cerastium* sp.), were taken in small amounts. Most of the May diet consisted of seeds from the previous year. Corn alone comprised 77.5 per cent of the food supply. Annual grasses, principally corn, comprised 88.5 per cent of the total, and 81.5 per cent was of agricultural plants.

June foods.—Data from 122 crops showed that corn again led during June, and constituted 51.4 per cent of the diet. By mid-June the harvest of wheat (*Triticum aestivum*) normally has begun in Missouri, and this grain becomes an important food. Wheat constituted nearly one-fourth of the food consumed during June, as the second most important food. Cranesbill (*Geranium carolinianum*) and wolf's-milk (*Euphorbia obtusata*) were important nonstaple seasonal foods at this time. The take of field-pansy, cottonwood, violets (*Viola* spp.), and buttercups continued in small amounts. At least 103 plant and 15 animal foods were identified from the June crops, but only eight plant foods comprised as much as 1.0 per cent each of the diet. Annual grasses, principally corn and wheat, made up 84.9 per cent of the total food, while agricultural plants comprised 75.8 per cent.

July foods.—Analyses of 148 dove crops collected during July showed that wheat had replaced corn as the principal food. Waste grain normally is readily available during July, and this item comprised 78.4 per cent of the diet. Corn ranked second at 9.0 per cent of the total. Only two other foods, small wild bean (*Strophostyles leiosperma*) and milk-purslane (*Euphorbia supina*), made up more than 1.0 per cent each during this month. The list of important foods thus was limited to four items in a total of 90 plant and 20 animal foods identified. Timothy (*Phleum pratense*), at 0.9 per cent, was the most important of other seasonal foods. Annual grasses constituted 90.2 per cent of the total, while 88.3 per cent consisted of agricultural plants.

August foods.—Only 8 plant species from a total of 96 plant and 12 animal foods identified in the 227 samples made up as much as 1.0 per cent or more each of the August diet. Wheat had become less important, and other staples had begun to appear in greater proportions. Wheat still was the most important single food, at 46.5 per cent of the diet, while yellow fox-

tail (*Setaria glauca*) was the second most important, with 19.5 per cent. The use of corn increased from 9.0 per cent during July to 15.5 per cent during August, as the third most important food. The August diet thus showed the typical change from summer to fall feeding by doves. Annual grasses constituted 88.1 per cent of the August diet, and 63.5 per cent of the total was seeds of agricultural plants.

September foods.—Examination of the 1,369 September crops showed the same "big-three" dove foods of August comprising the bulk of the diet, but in altered sequence. Yellow foxtail had attained greatest importance, being found in 74.9 per cent of the crops and comprising 32.0 per cent of the total volume of food. Corn was the second most important September food (21.4 per cent), while wheat, with 21.2 per cent, was a close third. Seven additional plant foods amounted to 1.0 per cent or more each, by volume. A total of 171 plant and 24 animal foods was identified. The take of annual grass seeds remained high, as 83.2 per cent of the food volume; the percentage of agricultural plant materials fell to 44.6 per cent of the total, due to the great consumption of foxtail grass seeds during September.

October foods.—Food-habits information for October is both too limited for accuracy and too localized to be typical for the state. The only information for this period comes from the analyses of 18 crops collected in Howell County in 1941 and one crop from Butler County during 1953. Cultivated millet (*Setaria italica*), cane (*Sorgum vulgare*), prairie-tea (*Croton monanthogynus*), and fall panic-grass (*Panicum dichotomiflorum*) made up the bulk of the diet. All these foods are of state-wide occurrence, but millet in particular is grown most extensively for livestock feed in the southern part of the state.

Principal State-wide Foods

State-wide average food data in Table 2 show the general usage of the more important foods throughout spring, summer, and fall. The need for average data was indicated by the great seasonal variation in feeding habits and disparity in numbers of samples collected each month.

The 10 most important plant foods, statewide, comprised 90.5 per cent of the diet, although at least 218 plant and 39 animal foods were identified in the crop contents. The 10 most used foods comprised 92.6 per cent of the food volume in northern Missouri, 87.9 per cent in southern Missouri, and 91.0 per cent in the southeastern lowlands—evidence that the same staple foods are sought throughout the state.

Average data, based upon the volume of food eaten, show that during months when doves are most abundant in Missouri, corn is the most used single food. Corn made up 35.0 per cent of the average diet. Corn is grown extensively throughout the state; heaviest utilization occurred during spring and early summer. Much of this grain is gleaned from feed lots, crib sites, and highways, since little is normally available to doves in the field during the summer. Corn used later in the fall presumably consists principally of fallen or waste grain, since doves are not known to damage the standing crops.

Wheat, also extensively grown, ranked second as a dove food. It comprised an average of 34.0 per cent of the spring, summer, and fall diet, and was taken by nearly one-half of the birds examined. This food was found each month from April through October, with greatest utilization in July following the wheat harvest. Presumably most of the wheat taken by doves was shattered or waste grain in the fields. It was used heavily from June through September.

Seeds of foxtail grasses (*Setaria* spp.) were found in dove crops during each month of collection, but in greatest amount during September. The six species identified in the crop contents were, in order of importance: yellow (*S. glauca*), giant (*S. Faberii*), cultivated millet (*S. italica*), green (*S. viridis*). All were taken in significant amounts, but two other species, (*S. verticillata*) and (*S. geniculata*) occurred as "traces." Together, these plants were the

third most utilized food and, as a group, provided 14.8 per cent of the total volume of food throughout the period. Virtually all of the cultivated millet was taken in southern Missouri, where the plant is grown extensively for livestock forage. The other foxtail grasses are generally distributed throughout the state, especially in waste and cultivated ground. The seed ripens during late summer and fall and is readily available to doves.

The preceding may be considered the staple foods of doves in Missouri; they comprise more than four-fifths of the total bulk. Additional foods, however, were taken in appreciable amounts. Three species of crotons (*Croton* spp.) were regularly eaten. Sand croton (*C. glandulosus*) was most heavily utilized, followed by hogwort (*C. capitatus*) and prairie-tea (*C. monanthogynus*). An average of 3.0 per cent of the dove diet was made up of croton seeds. In general these annuals thrive in sandy fields, grasslands, and waste places. They often are found in heavily grazed pastures, which provide good feeding places for doves. All the crotons are general in distribution in Missouri, with sand croton commonest in the central and southern parts of the state. The large tick-like seeds mature in the fall and provide an excellent, easily obtained food.

Small wild bean (*Strophostyles leiosperma*) and common ragweed (*Ambrosia artemisiifolia*) each were taken by approximately one-fourth of the birds, and amounted to 1.8 and 1.4 per cent, respectively, of the food bulk. Spurges (*Euphorbia* spp.) of at least eight species appeared frequently in the diet, and as a group accounted for 2.1 per cent of all foods. No individual species of spurge amounted to as much as 1.0 per cent of the food volume. For additional information on use of these and other foods, *see* Table 2.

Animal foods were taken in conspicuously small amounts, and collectively comprised 0.4 per cent of the total crop contents. No single item of animal food was found in an important amount in any month covered by this study, although individual birds occasionally fed heavily upon snails and insect galls.

Other investigators (Rosene, *op. cit.*; Moore and Pearson, 1941) have referred to the take of animal foods by doves as incidental or accidental. Jennings (*op. cit.*) and Pearson and Webb (*op. cit.*) indicated that snails probably were taken as gravel, while McClure (1943) suggested that the snails were selected to satisfy a physiological demand for calcium or salt.

In the present study, several birds were found that had consumed, along with other foods, large numbers of snails. The following three crops are given as examples: 46 *Gastrocopta armifera*; 54 *G. procera*, 3 *Succinea* sp., and 1 *Polygyra* sp.; 10 *Gastrocopta armifera*, 35 *G. procera*, and 7 *Pupoides marginatus*. Apparently, both live and dead snails were eaten. The consumption of live snails and the substantial numbers taken at a single feeding indicate that these foods were not picked up accidentally, but were selected to satisfy a physiological demand, as suggested by McClure (*op. cit.*). Snail consumption was greatest during June and July, when large numbers were found in both "lactating" and "non-lactating" adults of both sexes.

Gravel was found in approximately one-fourth of the crops. Amounts were small in all cases and averaged only 0.05 cc. per bird when found.

The danger in using a small number of samples, or data collected during one season, to draw conclusions regarding the important foods of a species was clearly demonstrated in this study. Some comparisons of the 1952 and 1953 data will serve as examples. June data showed that 7.6 per cent less corn was taken during 1953 than during 1952. Consumption of wheat was nearly the same, but yellow foxtail was 66 times more important in the June diet during the second year. The take of common ragweed was more than 10 times greater in 1953, while cranesbill was less important by 3½ times.

The September diet had apparently been established prior to 1953 by analyses of 1,261 crops. Yellow foxtail ranked first, as 34.4 per cent of the total. Yet analyses of

108 crops for 1953 showed only 3.2 per cent of this item. Average consumption of corn showed 22.6 per cent, with only 7.8 per cent for September 1953. Consumption of wheat averaged 16.3 per cent for September, while 78.0 per cent of the September 1953 diet was of this food. These data substantiate those of Leopold (*op. cit.*): during most years doves feed heavily upon seeds of foxtail grasses during September, but when production of this seed is poor, they rely upon wheat and other waste grain until the later-ripening weed seeds mature in the fall.

The difference in dove feeding habits mentioned here may be abnormally pronounced, due to the cumulative effect of two years' drought, which limited weed-seed production throughout most of Missouri during 1953. The differences in feeding habits of doves may be attributed, in part, to this cause. The comparisons do clearly emphasize, however, the ease with which erroneous conclusions may be drawn from a limited sample.

MANAGEMENT IMPLICATIONS

Although doves use many plant foods, it is evident that they rely most heavily upon certain of these as staples. The 10 most important foods, which comprised 90.5 per cent of the average diet, included eight genera in four plant families: grasses (Gramineae), spurges (Euphorbiaceae), legumes (Leguminosae), and composites (Compositae).

A total of 48 plant families were represented in the diet. Tabulation of the principal families in order of importance shows the following: 47 species of Gramineae contributed 87.0 per cent; 17 species of Euphorbiaceae, 5.3 per cent; 20 species of Leguminosae, 2.1 per cent; 15 species of Compositae, 1.5 per cent; and 1 species of Geraniaceae, 0.6 per cent of the average food supply. The family Polygonaceae supplied 0.4 per cent; Salicaceae, 0.3 per cent; Phytolaccaceae, Violaceae, and Oxalidaceae, each 0.2 per cent; and Malvaceae, Amaranthaceae, and Boraginaceae, 0.1 per cent each. The remaining 35 families were represented by "trace" amounts.

There was no evidence of food shortages or that doves had to resort to inferior or undesired foods during any of the months covered by this study. The fact that more than two-thirds (70.8%) of the food consumed was from agricultural crops assured adequate food supplies in the form of waste or otherwise accessible grain over most of the state. No complaints of damage to field crops by doves in Missouri have come to the investigator's attention. Moore and Pearson (*op. cit.*) pointed out that doves do not seek food by scratching or digging, but eat foods lying readily available. Thus doves do not harm newly planted crops. Leopold (*op. cit.*) mentions the inability of the dove to cling to upright stalks and twigs, which may explain absence of damage to standing grain by doves. Grains eaten consist principally of that portion the consumption of which cannot be considered to be an added economic loss. The feeding habits of the mourning dove, therefore, are heavily inclined toward consumption of large quantities of waste grains and unwanted weed seeds.

Little concrete information is known about food as a limiting factor on the dove population. A major part of the doves' food economy is now geared to grain farming and to feed lots, as shown by this study. Future developments in agricultural practices may potentially affect the food resources of doves. These changes include new varieties of small grains with less tendency to shatter, new methods of harvesting by improved machines with much less wastage, new methods of feeding livestock, development of new herbicides that will limit *Setaria* and other important dove food plants, and so on. Changes such as these cannot always be foreseen, but the wildlife manager must be constantly aware that any changes in farming techniques may materially affect the problem of dove management.

SUMMARY

At least 218 plant and 39 animal foods were identified in the crop contents of 2,000 doves collected in 55 of Missouri's 114 counties over a 7-months' period—April through October—mostly from 1951 to 1953.

The 10 most important foods, which comprised 90.5 per cent of the total volume, included eight genera in four plant families—grasses (Gramineae), spurges (Euphorbiaceae), legumes (Leguminosae), and composites (Compositae). Average percentages for the principal foods from May through September were: corn, 35.0; wheat, 34.0; yellow foxtail, 11.7; giant foxtail, 2.4; small wild bean, 1.8; sand croton, 1.4; common ragweed, 1.4; hogwort, 1.3; cane, 0.8; and painted-leaf spurge, 0.7, by volume. April and October data were omitted from the computed averages because they were insufficient. Seeds from 48 plant families made up 99.2 per cent of the average diet, but 35 families were represented only in "trace" amounts. Animal foods, principally snails, comprised 0.4 per cent, and gravel the remaining 0.4 per cent. Major changes in the feeding habits of doves were noted from month to month and year to year.

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AN AUTOMATIC BAT-COLLECTING DEVICE

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Previous methods of collecting bats are satisfactory in many situations, but each has inherent limitations in usefulness. Shooting requires considerable experience and produces damaged or dead specimens. Nets of the insect-catching variety (Lyman, 1926) and modifications of the same produce only one bat per thrust in most situations and are usually effective only in close quarters. Gill nets (Jackson, 1926) are useful in some instances, but Japanese "mist nets" (Dalquest, 1954) are particularly effective. However, the latter require constant attention, for captured bats quickly become entangled, requiring considerable time to extract them, and if unattended, the net is soon damaged by bats that attempt to and frequently succeed in escaping by chewing their way to freedom, producing gaping holes in the net. My experience has shown that, if large numbers of bats are captured at one time, the bats and net become a hopelessly entangled mass. Griffin (1940) described the use of "tunnel nets" and metal or celluloid cylinders for capturing bats as they leave small openings in buildings, and he introduced the use of smooth-sided trap receptacles for housing captured bats, eliminating the necessity of cage doors. Similarly, the author has used glass or plastic sheets, placed in a vertical position at building roost exits, such as Spanish tile roofing openings; bats strike the obstruction and slide into a smooth-sided container below. Borrell (1937) captured bats by tripping them with taut wires, arranged horizontally just above the water surface of open water tanks, from which flying bats drink by scooping mouthfuls of water. This remarkable method requires constant attention, or the bats will escape or drown. Bats may be extracted from roosts with long forceps, a hooked wire, or by hand. Numerous modifications of the above procedures, as well as less satisfactory techniques, have been employed. These methods, each being desirable under certain circumstances, lack adaptability to all situations, and none fully satisfies the need arising when thousands of flying bats must be captured unharmed in open space or in such places as large cave entrances. Furthermore, most of these techniques require considerable experience in the field and the presence of an operator.

The discovery of bat rabies in the United States (Venters, *et al.*, 1954) and subsequent developments in this field stimulated the author to devise an automatic bat-collecting device to implement field investigations in this area. The disclosure by Griffin and Galambos (1941), that by means of echo location certain species of bats are capable of detecting and avoiding fine wires, led to the thought that even finer wires might be employed to capture bats. Preliminary experiments by the author disclosed that flying bats of the genera *Myotis*, *Lasiurus*, and *Tadarida*, when released in a room for the first time, apparently failed to detect a grid of taut 0.006-inch wires, arranged vertically and spaced 1 inch apart. Bats would fly into the grid, slide down the wires, and fall into a receptacle at the bottom of the grid. However, the larger bat species occasionally broke the wires, and since it was soon determined that *Tadarida* and *Lasiurus*, which are of particular interest in the bat rabies study, could be trapped indoors by wires of a greater diameter, 0.012-inch, the latter size was employed thereafter. Further development resulted in several varieties and uses of bat traps, as follows.

Carlsbad Cavern Bat Trap

During operations at Carlsbad Caverns National Park, New Mexico, in 1956, it was necessary to make daily collections of quan-

tities of Mexican freetail bats, *Tadarida brasiliensis mexicana,* for sampling and banding. The nature of the cavern rendered conventional methods of capture impractical. Thereupon, a large bat trap was constructed and installed in the cavern entrance; since then, it has been used regularly.

The trap (Figs. 1, 2) consists of a rec-

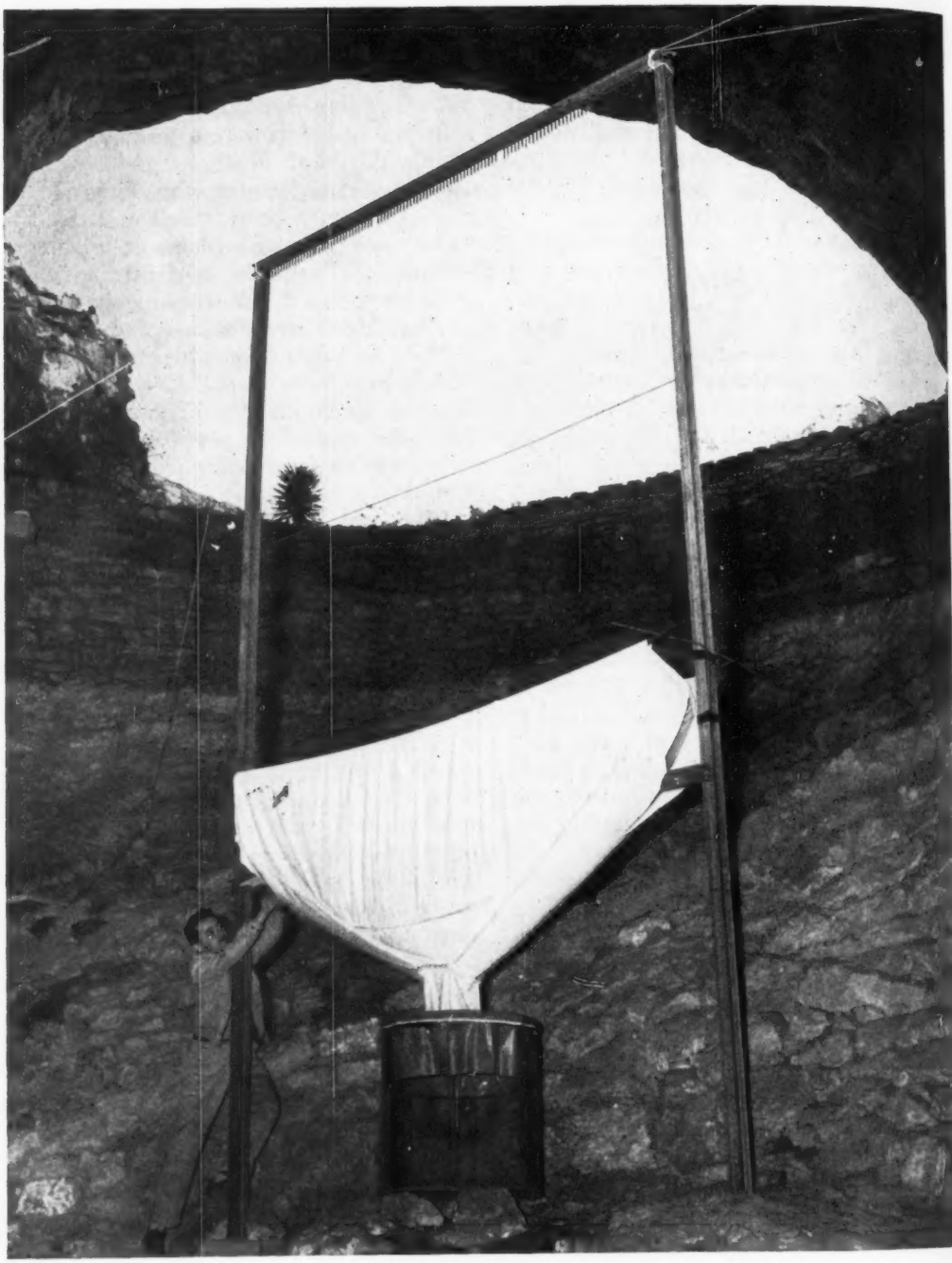

FIG. 1. Bat trap at Carlsbad Cavern. Photo by Tex Helm.

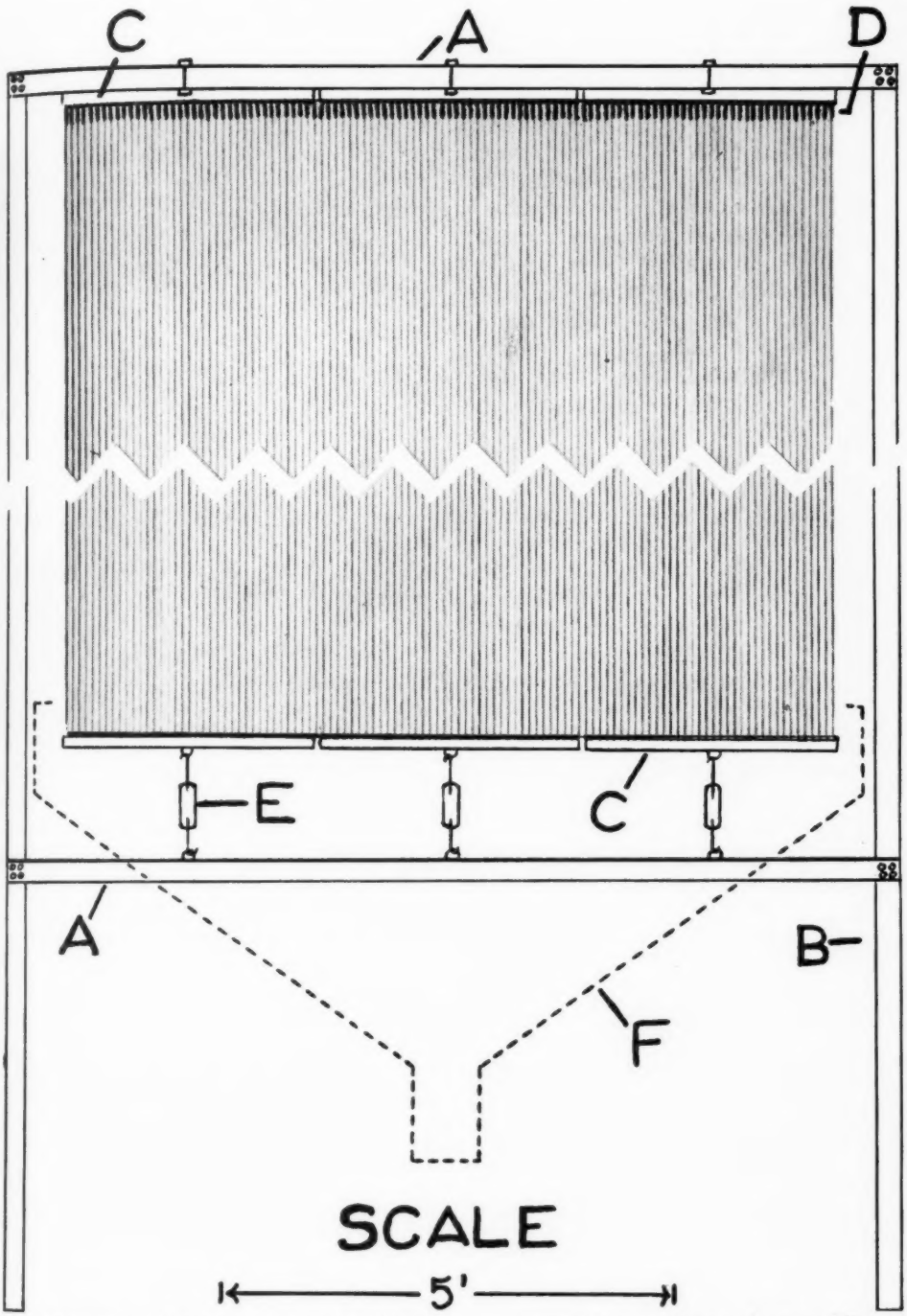

FIG. 2. Diagram of bat trap used at Carlsbad Cavern. Jagged lines indicate where middle section of diagram has been eliminated. *A*, 3-inch aluminum channel. *B*, 20-foot, 3-inch aluminum I beam. *C*, 1½-inch angle iron, each 3-foot length of which bears 36 0.012-inch stainless-steel music wires. *D*, row of coil springs, each spring fastened to angle iron above and wire below. *E*, 8-inch turnbuckle, used to apply tension to wires. *F*, outline of plastic-lined cloth funnel.

tangular aluminum frame, supporting vertically arranged 0.012-inch stainless-steel music wires, spaced 1 inch apart and kept taut by individual coil springs, which attach each wire at the top. Flying bats encounter the wires, slide down them, and fall into a large, plastic-lined cloth funnel; thence they pass into a cage, from which they cannot escape. The vertical sections of aluminum frame are 20-foot lengths of 3-inch I beam, and the horizontal sections are 10-foot lengths of 3-inch channel. Stove bolts attach the horizontal sections to uprights at the top of the frame and at a point 5 feet from the bottom, providing space below for the funnel and cage. Each of three sets of 36 wires is connected at upper and lower ends to 3-foot lengths of 1½-inch angle iron, the upper angle iron being bolted to the top of the frame, the lower one being fastened to the bottom of the frame by an 8-inch turnbuckle. Tightening the turnbuckle permits adjusting stress on the wires to a desired 7 pounds for each wire. It is vital that each wire be very taut, clean, and free of rust. A cold-rolled ¼-inch steel-rod framework is employed to suspend the funnel. The cage is an iron rod-framed hardware-cloth barrel, 30 inches high and 27 inches in diameter. The top of the cage is open, permitting entry of bats, but a 1-foot flap of pliable plastic prevents escape by this route. Freetail bats cannot fly out of the cage opening, and they cannot crawl over the smooth plastic.

Over 45,000 Mexican freetail bats were captured by this trap in 1956. Single individuals of the pocketed bat, *T. femorosacca*, the big freetail bat, *T. molossa*, the western pipistrel, *Pipistrellus hesperus*, and the fringed bat, *Myotis thysanodes*, were also captured. Trap efficiency would be difficult to ascertain, depending on many things including weight and condition of bat and angle and speed of approach. A good percentage of specimens bounced off the wires and recovered flight. Others fell through the wires, continuing flight on the opposite side. In order to tie down the trap securely, it was placed in an unfavorable situation, where most bats encountered the wires at an oblique angle. Nevertheless, the trap produced sufficient quantities of bats, none of which appeared to have been injured by the experience. It was first feared that fast-flying bats, entering the cavern, might be injured when striking the wires. It became evident, however, that returning bats reduce speed when just inside the cavern entrance, and they gently spiral down and strike the wires with about the same force as do outgoing bats.

SMALL TRAPS

It was considered desirable to prepare small bat traps for use in small cave entrances and in other situations. A two-by-four wood frame, 6 by 6 feet square, was constructed, and wires with attached springs were fastened in position with nails. A permanent hardware-cloth repectacle, 6 feet long, 1 foot wide, and 18 inches deep, was attached to the bottom of the trap. A 17-inch flap of flexible plastic was affixed at the edges of the open top of the receptacle and allowed to hang inside, providing a smooth surface to prevent escape of captured bats. This trap (Fig. 3) was suspended over a pond and illuminated by a light, which was attached at one side to one of the vertical two-by-fours, directing the light beam across the wire grid. In several nights of use the trap captured three desert pallid bats, *Antrozous pallidus*, but many little California bats, *Myotis californicus*, successfully avoided capture. This type of arrangement remains to be tested under varied conditions.

This variety of trap was tested indoors, where it proved successful in capturing hoary bats, *Lasiurus cinereus*, Seminole bats, *L. seminolus*, and eastern freetail bats, *Tadarida brasiliensis cynocephala*, but, except when the smaller 0.006-inch wires were used, the trap only occasionally captured the Mississippi myotis, *Myotis austroriparius*. Electrifying the wires produced nearly 100 per cent success, but burned wing membranes usually resulted.

A similar trap was employed in the entrance of a cave, near Valles, San Luis Potosí, Mexico, where it captured over 1,400 bats

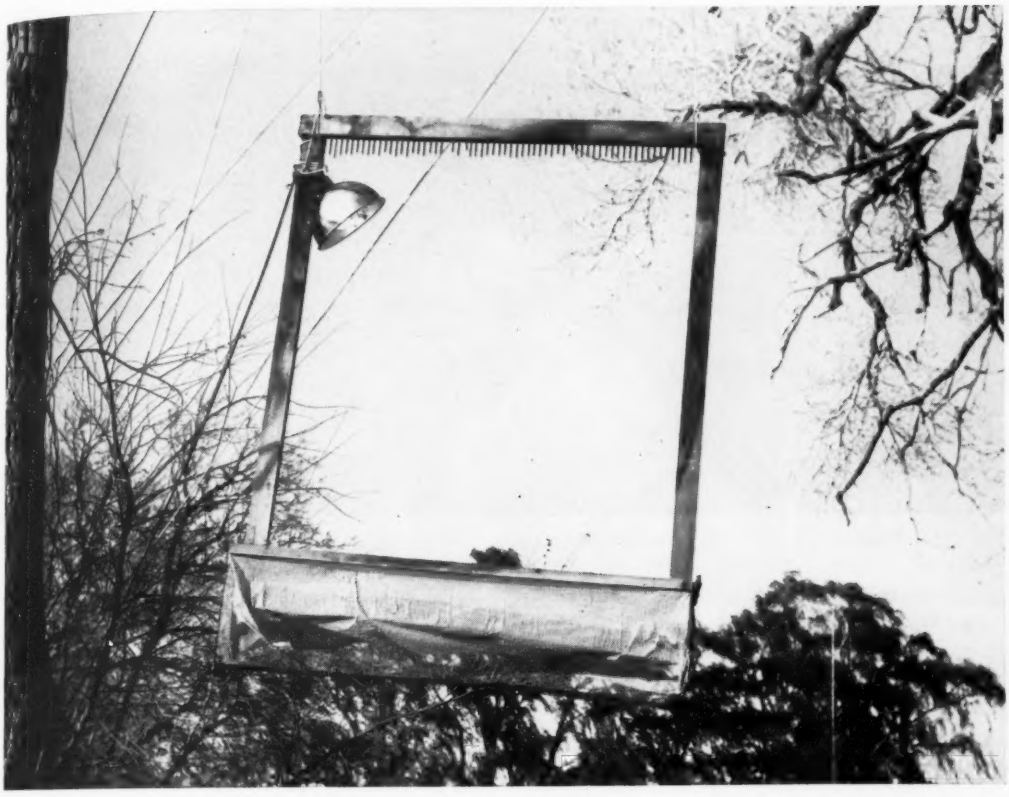

FIG. 3. Small bat trap suspended from tree limb with light to attract flying insects. Photo by A. T. Hewitt.

in a single evening. The following species were represented: *Glossophaga soricina, Artibeus jamaicensis, Chilonycteris rubiginosa, C. psilotis, Pteronotus davyi, Mormoops megalophylla, Natalus mexicanus,* and the common vampire, *Desmodus rotundus* (Fig. 4). The same trap and several similar traps were used to cover the open side of a calf shed, where a common vampire was trapped as it attempted to enter.

PROJECTED USES OF BAT TRAPS

The present descriptions and experiences with bat traps are presented to satisfy the many requests that have been received for this information. It is anticipated that these traps will prove useful, not only in routine collecting, but in providing information on migration by facilitating capture of great quantities of bats to be banded and in the search for banded individuals. Bat-drinking sites and lights may prove useful in attracting bats into traps, lights attracting insects which the bats pursue. Other attractants are being tested. These methods may implement many types of study and provide a means of determining population density/species/trap/area/time unit, with heterothermy and inherent mechanical disturbances as omnipresent variables. However, such a technique, regularly employed at any given site, might be of value for only a limited time, for the experiments of Novick (Van Gelder, 1956) indicate that bats become conditioned to the presence of obstacles, as evidenced by continuing to avoid them after they are removed. The use of bat traps as a vampire-control mechanism is being proposed elsewhere. The trap should find immediate service in the many bat-

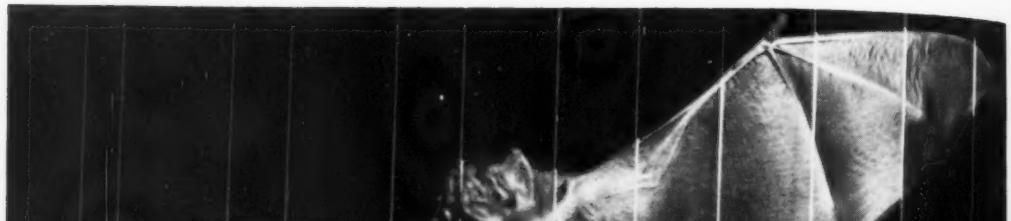

FIG. 4. Common vampire bat, *Desmodus rotundus*, encountering trap wires. Photo by A. T. Hewitt.

rabies surveys now in progress or pending.

Whereas the trap, as employed, lacks efficiency in capturing *Myotis*, it seems particularly useful in capturing the narrow-winged, fast-flying molossids and lasiurine species, which are of great interest in rabies studies, because they appear to be our main migrants. However, *Lasiurus* was tested indoors, and field capture may require finer wires. It is noteworthy that bats are unharmed by the experience, and traps work automatically, requiring infrequent examination in most situations, and the mechanism may be employed by the novice, eliminating the necessity of experience in bat collecting. The size and weight of these bat traps provide objections which are now under study.

SUMMARY

A method of trapping bats, employing fine, taut wires, arranged vertically and spaced 1 inch apart, was tested indoors and in the field. Bats were captured when they flew into the wires, slid down them, and dropped into a receptacle. *Myotis austroriparius* was captured indoors when 0.006-inch wire was used, *Lasiurus cinereus, L. seminolus,* and *Tadarida brasiliensis cynocephala* being captured by 0.012-inch wire.

Antrozous pallidus was captured in the field with 0.012-inch wire, but *Myotis californicus* avoided capture. Traps with wire of this size were used in cave entrances, where the following species were captured: *Tadarida brasiliensis mexicana, T. femorosacca, T. molossa, Pipistrellus hesperus, Myotis thysanodes, Glossophaga soricina, Artibeus jamaicensis, Chilonycteris rubiginosa, C. psilotis, Pteronotus davyi, Mormoops megalophylla, Natalus mexicanus,* and *Desmodus rotundus.*

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BIRD POPULATIONS IN RELATION TO CHANGES IN LAND USE

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As part of the program of wildlife investigations on agricultural lands, started in August 1946 by the Fish and Wildlife Service,[2] an old, partially abandoned farm was converted into a modern, productive conservation farm. Incidental to this change in land use and to population studies on other wildlife, censuses were made of breeding and wintering songbirds. This paper deals mainly with population changes as they occurred among the nesting birds over a six-year period.

Literature relating to bird-population studies on farmland undergoing extensive cover changes is limited. Effects of various land-use practices on songbirds have been reported by Dambach and Good (1940), Monson (1941), and Wandell (1948). Also, the influence of fence rows, hedges, and field borders is described by Dambach (1942), Steavenson (1946), and Rosene (1951).

Study Area

The study area is on the Patuxent Research Refuge, on the Atlantic Coastal Plain only a few miles from its inner boundary and about halfway between Washington, D. C., and Baltimore, Maryland. Soils are generally acid, low in organic matter, and vary from well-drained to poorly drained. Fertility apparently never has been high.

Forests of mixed hardwoods and pines surround the farm to form an "island" of cleared land. This isolation, together with the scarcity of farms in the general area, tends to keep farm-wildlife movement to and from the area at a minimum.

When clearing work started, late in 1946, about 34 acres were being tilled (*see* Fig. 1). Old, weedy fields, not cropped for two or three years, totaled 40 acres. Fields abandoned for ten years or more amounted to 63 acres and contained brushy growth, mostly Virginia pine (*Pinus virginiana*) and sweet gum (*Liquidambar styraciflua*). A detailed account of vegetation found in fallow and abandoned fields at the Patuxent Refuge is given by Hotchkiss and Stewart (1947). In addition to the 137 acres of tilled and idle fields described above, there were 39 acres of woods, roads and roadsides, building areas, and odd areas unsuited to cultivation. The entire farm thus totaled 176 acres.

Although many plant species were present in weedy and brushy fields, there was a good deal of uniformity of height and density throughout each habitat type. A greater diversity of ground cover existed in the partially cleared, brushy fields. Here, locally, there were bare ground where bulldozer work was recent, upturned stumps and brush piles, and areas still containing standing saplings and shrubs. Crop fields constituted another diverse habitat type consisting of varying acreages of grasses (hay and pasture), corn, and wheat. Since corn was either just sprouting or still below ground at the season when the censuses were made, corn fields were classed as bare ground. Prospective hay fields being readied for seeding added some acreage of bare ground. Wheat at census time was nearly mature, with well-developed heads.

In addition to removal of plant cover from the abandoned fields, grading was done to improve water runoff. Tile drains and surface ditches were constructed to correct poor drainage in some fields. On a number of slopes, diversion terraces were installed to reduce erosion. The water from two springs was diverted to dry up wet areas in a field that was to be a pasture. These ac-

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[1] Present address Michigan Department of Conservation, Lansing Michigan.

[2] The Soil Conservation Service, U.S. Department of Agriculture, has cooperated throughout the project. Their need for management information led the two agencies to set up the experiment.

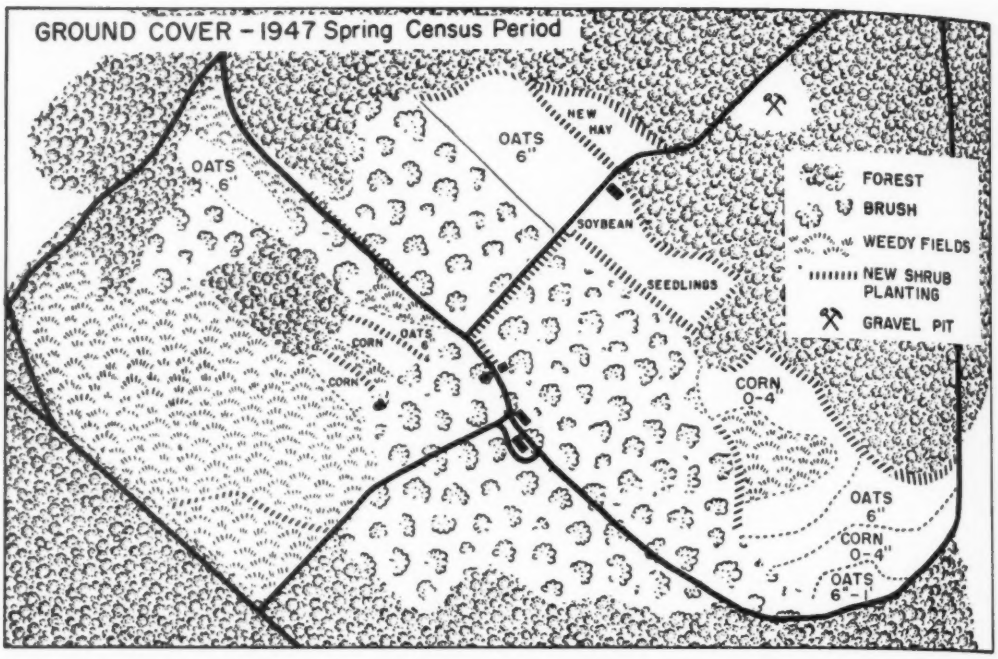

FIG. 1. Farm at time of first census: 34 acres cropped; 40 acres of 2- to 3-year-old abandoned fields; 63 acres of fields abandoned 10 or more years.

tivities eliminated the former scattered wet areas, many of which had persisted the year around. As a result, the wet areas were largely reduced to two drainage ditches, some temporary wet spots in surface drains, and a spring. These ditches bound one of the pastures on two sides and provided the only semblance of marsh habitat on the farm. In September 1950, another source of permanent water became available when a one-acre farm pond was constructed.

As idle fields were being readied for crops, shrubs were planted in various sites. When the spring census began in 1947, some field borders, multiflora rose fences, and contour hedges had been planted. However, these consisted of young plants and were barely in leaf when the first census was made. Thereafter, plantings were made annually until 1953, resulting in various-aged stands through the census years (*see* Fig. 2). Principal plantings in the field borders and contours included multiflora rose, shrub lespedeza (*Lespedeza bicolor*), various other species of lespedeza (*L. sericea, L. intermedia, L. juncea,* and others), silky cornel (*Cornus amomum*), tartarian honeysuckle (*Lonicera tatarica*), hybrid filbert (*Corylus* sp.), and autumn olive (*Eleagnis umbellata*).

CENSUS METHOD

The method used in censusing breeding-bird populations was one that had been used at the refuge by other workers (Stewart, Cope, Robbins, and Brainerd, 1952). Basically, the technique was similar to that reported by Williams (1936). The observer walked north and south lines spaced 330 feet apart and plotted on maps all birds seen or heard. One map was used for each of the eight trips in a season. Additional information on birds carrying nesting material or food was also recorded. Birds of the same species heard singing simultaneously furnished particularly useful information for plotting territories. Later, on separate species maps, the clustering of records formed the bases for outlining the approximate territories. A cluster of four or more records for a species was arbitrarily selected as indicating an established terri-

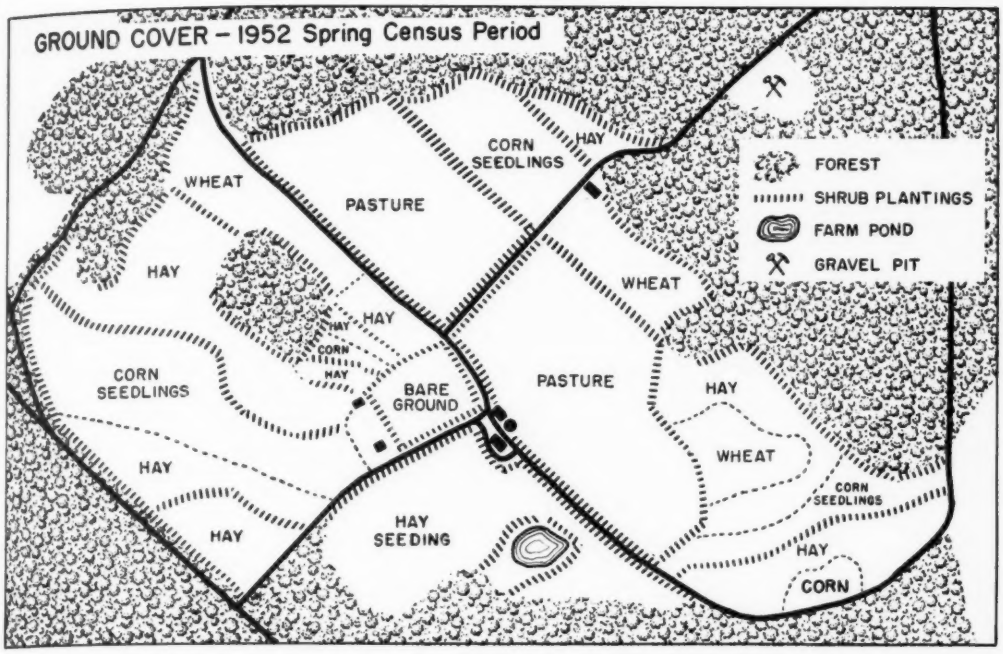

FIG. 2. At the time of the sixth spring census, all fields were being tilled and 5 miles of plantings had been installed.

tory. Territories then were considered to represent the number of nesting pairs.

Spring census periods generally were during the last two weeks of May, and counts were made during the early morning hours (start 6:15–7:00 A.M., E.D.T., end 10:00–10:30 A.M.). Observers were biologists of the refuge staff. Their number varied from three in 1947 to seven in 1949 and 1952. All birds seen or heard on the farm and along the surrounding woods edge were recorded on the maps. In 1952, for example, 93 species of birds were recorded. Many of these, however, included forest-dwelling, migrant, late-nesting, and free-flying birds, either not readily censused by the method used or with territories off the farm area. Only those believed to have established territories, or known to have a nest on the area, were listed as "nesting species."

POPULATION CHANGES

Table 1 shows the total number of species encountered on each census and the total number of species and pairs believed to have established territories on 210 acres of the farm, including a 150-foot zone within the surrounding forest. It will be noted (Table 1 and Fig. 3) that, as the farm lost its brush and weed fields, and as cultivated crops were put in, the number of nesting species and nesting pairs decreased, although the total number of species seen increased. It is not implied that such population changes were wholly the product of habitat modifications, independent of other factors such as disease and climate.

Seven of the most abundant species (Table 2) showed the greatest reduction as land use changed. Collectively, the de-

TABLE 1.—TOTAL NUMBER OF SPECIES AND TERRITORIES

	1947	1948	1949	1950	1951	1952
Number of species	55	50	43	62	80	93
Number of nesting species	43	39	38	32	38	37
Number of nesting pairs	262	236	245	138	172	147

TABLE 2.—PRINCIPAL BIRD SPECIES OF THE EXPERIMENTAL FARM, 1947–52

Species	Number of Pairs in Each Year					
	'47	'48	'49	'50	'51	'52
Prairie warbler	34	26	22	6	6	1
Yellowthroat	33	24	27	25	20	19
Field sparrow	19	23	20	15	12	12
Rufous-sided towhee	17	16	15	11	12	11
White-eyed vireo	15	10	13	3	2	2
Catbird	13	19	10	6	5	4
Yellow-breasted chat	12	8	12	7	3	4
Indigo bunting	12	15	18	14	20	20
Song sparrow	4	2	5	2	2	5
Chipping sparrow	4	4	4	5	5	3
Cardinal	3	5	5	6	6	4
Henslow's sparrow	3	4	0	3	0	1
Eastern kingbird	2	3	3	3	3	3
Eastern bluebird	2	2	1	1	3	+
Blue jay	2	2	1	1	1	+
Mockingbird	1	0	1	1	3	2
Grasshopper sparrow	1	2	1	1	2	3
Robin	+	+	1	1	3	1
Redwinged blackbird	+	0	+	+	2	3
Killdeer	0	1	1	1	1	1
Eastern meadowlark	0	0	0	3	4	3

The symbol + means recorded on fewer than 4 of the 8 census trips of this year.

crease in this group amounted to 62 per cent. Since these species are partial to habitat consisting of brush or fallow fields, it is not surprising that their numbers dropped as more acreage was put into crops.

Restoring some brush habitat by means of wildlife plantings of multiflora rose and other shrubs did not reverse the downward trend of breeding-bird populations, but a leveling off, observed during the last three years, may indicate that for some species an adjustment to the new pattern was made. Although several miles of edge were provided by plantings, the amount and area of brushy cover was much less than when the censuses began. By 1952, 2.3 miles of multiflora rose fences, 1.6 miles of field borders, and 1.1 miles of contour hedges had been planted. Impressive as these figures appear, their area totals only about 8 acres, as compared with 63 acres of brush present in 1947. Numbers of a few species that frequent open fields, notably the eastern meadowlark, increased as brushy cover and fallow fields were reduced.

Twenty-one of the more common species breeding on the experimental farm are listed and discussed below in the order of their abundance during the first census year, 1947. For each species, information given includes: (1) a series of figures denoting the number of breeding pairs (+ signs indicate fewer than four observations for a pair during the eight census trips) during each year of the 1947–52 period, and (2) comments on habitat changes or other factors that seem related to the population changes.

Birds such as the house wren (*Troglodytes aedon*), eastern phoebe (*Sayornis phoebe*), and barn swallow (*Hirundo rustica*) that commonly nest in or near man-made structures have been omitted from this account, although they are locally among the more numerous species.

PRAIRIE WARBLER (*Dendroica discolor*). Six-year record: 34–26–22–6–6–1. This most abundant of species in 1947 showed the greatest decrease, 97 per cent, by 1952. Biggest drop occurred between 1949 and 1950 when brush clearing was at its height. Plantings did not stop decline. Four pairs present along a band of pines in 1949 were reduced to one in 1950, although there was no clearing in the vicinity. A 5-row planting of bicolor lespedeza bordered the pines during the two years.

YELLOWTHROAT (*Geothlypis trichas*). Six-year record: 33–24–27–25–20–19. In 1947, 20 had territories in brushy fields, 13 along woods and wild

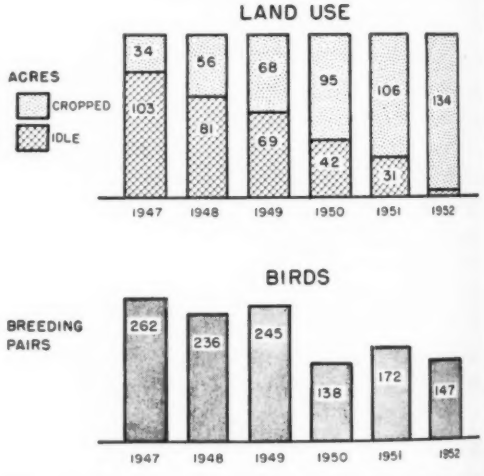

FIG. 3. Changes in bird numbers in relation to changes in land use—the latter involving reduction in acreage of weedy and brushy fields with an increase of crop fields.

hedges at edges of cropped fields. Breeding population declined moderately as the farm was reconstructed. In 1952, none were in fields, 14 along woods edge surrounding farm, and 5 had territories that included multiflora rose fence. Shared the-most-numerous class with indigo bunting the last two years. Appeared to level off and become adjusted to changes.

FIELD SPARROW (*Spizella pusilla*). Six-year record: 19–23–20–15–12–12. Early territories mostly in or at edges of brushy fields. Distribution in 1952, for 10 of the 12 territories plotted, was around edge of farm. Included in area of activity for most of the 12 pairs was either a rose fence, a shrub border, or a contour hedge.

RUFOUS-SIDED TOWHEE (*Pipilo erythrophthalmus*). Six-year record: 17–16–15–11–12–11. Pattern of distribution changed as clearing progressed. As brushy fields were converted to crops, territories appeared along the woods edges surrounding farm. Plantings failed to attract any back to the interior of farm.

WHITE-EYED VIREO (*Vireo griseus*). Six-year record: 15–10–13–3–2–2. Dropped sharply in 1950 when clearing work was at maximum. Breeding population appeared to stabilize at two pairs. No use of plantings noted.

CATBIRD (*Dumetella carolinensis*). Six-year record: 13–19–10–6–5–4. In the first three years, 1947–49, an average of 14 pairs was present, mostly in undrained, brushy fields. After clearing, breeding population dropped. Three of the four pairs in 1952 were along woods edge surrounding farm, one in farm wood lot. No evidence that wildlife plantings were used.

YELLOW-BREASTED CHAT (*Icteria virens*). Six-year record: 12–8–12–7–3–4. In 1947, most of the 12 pairs used brushy fields in interior of farm; in 1952, three of the four pairs were in woods edge around farm, one along a multiflora rose fence. A few early shifts in territories occurred along woods edge at some distance from brush-clearing area. Some use of plantings indicated.

INDIGO BUNTING (*Passerina cyanea*). Six-year record: 12–15–18–14–20–20. Increased after land changes were made. Territories before clearing were mostly along edges of brushy fields and surrounding woods. After clearing and planting, 75 per cent of pairs were along woods edge (surrounding farm and in central wood lot) and 25 per cent in central section where rose hedges and other shrub plantings were included in territories. Highest concentration was in 1948 when slightly more than one per acre were found in the 4.7-acre residence area, where tangle of vines and brush occurred among some large trees.

SONG SPARROW (*Melospiza melodia*). Six-year record: 4–2–5–2–2–5. More than half of total territories were around the centrally located residence. Plantings around buildings and elsewhere held birds in this area after clearing operations. Two pairs established territories near pasture and included a multiflora rose fence within their range of activities.

CHIPPING SPARROW (*Spizella passerina*). Six-year record: 4–4–4–5–5–3. Farm conversion had little effect upon breeding populations. Before plantings were made, territories were in and around cultivated fields and at the edge of brush areas. After clearing, most territories were in same general types of cover: woods edge, shrubs around buildings, and in some of the linear plantings.

CARDINAL (*Richmondena cardinalis*). Six-year record: 3–5–5–6–6–4. Breeding population remained fairly uniform. Stability of numbers possibly due to presence of most territories along relatively unchanged woods edge surrounding farm.

HENSLOW'S SPARROW (*Passerherbulus henslowii*). Six-year record: 3–4–0–3–0–1. Disappearance of weedy fields and mowing of hay fields appeared to account for decline in breeding populations during the second half of the six-year period. No evidence that shrub plantings had any effect on establishment of breeding territories.

EASTERN KINGBIRD (*Tyrannus tyrannus*). Six-year record: 2–3–3–3–3–3. Land changes had little effect upon breeding populations. During first few censuses, territories included partly cleared brushy areas. From 1950 on, crop fields plus either woods edge, shrubs around residence, or plantings were included in their territories. In 1949, a nest was found in a young silky cornel contour hedge. Use of plantings as perches repeatedly observed.

EASTERN BLUEBIRD (*Sialia sialis*). Six-year record: 2–2–1–1–3–+. Fluctuated during the six-year census period; highest count of three pairs in 1951 when large amount of clearing had been completed. Territories centered around farm buildings and homesite. No pairs in 1952, although there was little change in landscape.

BLUE JAY (*Cyanocitta cristata*). Six-year record: 2–2–1–1–1–+. Generally established territories in wooded areas that were not disturbed during census years. Removal of brush had only slight effect; plantings had none.

MOCKINGBIRD (*Mimus polyglottos*). Six-year record : 1–0–1–1–3–2. Territories were mostly near residence. In 1952, one pair centered activities around a multiflora rose hedge. Data from winter censuses showed more use of multiflora hedge in that season than during spring period. These plantings believed definitely beneficial to mockingbirds on a year-round basis.

GRASSHOPPER SPARROW (*Ammodramus savannarum*). Six-year record: 1–2–1–1–2–3. Increased slightly as grass acreage increased. Early in study, some territories were in well-drained fallow weedy

fields as well as in hay fields. After clearing, hay fields were predominantly used. No indications that shrub plantings were used.

ROBIN (*Turdus migratorius*). Six-year record: +–+–1–1–3–1. One pair nested in residence area from 1949 onward, despite clearing operations. Only two other territories were plotted, both in 1951, along woods edges. One woods edge had a border planting, the other did not.

REDWINGED BLACKBIRD (*Agelaius phoeniceus*). Six-year record: +–0–+–+–2–3. This species did not nest on the farm until marshy plants developed in a new drainage ditch in 1951.

KILLDEER (*Charadrius vociferus*). Six-year record: 0–1–1–1–1–1. Presence of bare or nearly bare ground appeared to be essential territorial requirement. Increase or decrease in acreage of bare ground from year to year caused no deviation from the single territory established annually.

EASTERN MEADOWLARK (*Sturnella magna*). Six-year record: 0–0–0–3–4–3. Definitely correlated with increase in grassland acreage. No use of plantings noted.

DISCUSSION

The major changes in bird populations reported here must be attributed less to the kind of farming practiced than to the transformation of swampy thickets and upland second growth to farmland. Species largely dependent upon dense growth for both foraging and nesting, such as the prairie warbler, white-eyed vireo, yellow-breasted chat, and catbird showed striking decreases in breeding population following the clearing of brush. Field sparrows, towhees, and yellowthroats also declined with the loss of cover, but to a lesser extent. The indigo bunting was the sole species abundant at the outset that found new conditions superior to the brushland.

With the exception of these species, breeding birds were distributed so sparsely over the farmland that it is not possible to draw many valid conclusions as to the effects of conservation farming on their numbers. The mockingbird increased during the study from 1 to 2 or 3 breeding pairs. Banding results in 1955 showed at least 39 mockingbirds on this area: 10 adults and 29 birds of the year. Thus, a relatively small number of breeding pairs provided with good nesting sites might result in a marked increase in summer and fall bird populations.

SUMMARY

Changes in breeding-bird populations on a 210-acre farm area were observed from 1947 to 1952. During this period, clearing, drainage, and planting changed the area from a partially abandoned farm with only 34 acres in cultivation to a modern conservation farm. Number of bird species nesting in the area was about 10 per cent lower in the last three years than in the first three years; number of nesting pairs declined about 40 per cent.

The greatest decline was in species characteristic of brushy habitat; these were the most abundant birds on the area at the start of the study. For these species, approximately eight acres of planted hedges and field borders did not serve as an adequate substitute for 63 acres of brushy fields. Other birds were so limited in number during the breeding season that it is unsafe to conclude what effect agricultural practices had on their populations.

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AGING GRAY SQUIRRELS BY USE OF TAIL-PELAGE CHARACTERISTICS[1]

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Age determination of gray squirrels (*Sciurus carolinensis*) has been based chiefly on sex organs of the male and size of nipples in the female. These characters, when integrated with total body weight, shape and size of tail, may give a clue to age. But the investigator probably will not be able to age more than 60 per cent of all squirrels correctly at any season of the year by this method.

The appearance and nature of sex organs and nipples in gray squirrels present a variety of confusing individual gradations. In males, the testes vary in size from season to season. Those of subadults may be enlarged, but the scrotum is usually completely furred, while in adults the posterior covering of the scrotal sac may be bare, dark, and wrinkled. Three males that I tagged in 1951 and recorded as having the scrotum furred, when retaken in 1952 and 1954, had scrotal sacs that were relatively unchanged. The ear tags gave positive evidence that they were adult squirrels.

The area on which much of the work was conducted for the present study was set aside by the School of Forestry at The Pennsylvania State University for permanent squirrel management as part of the university's multiple-use program in the Stone Valley Experimental Forest in Huntingdon County, Pennsylvania. A study of the squirrel population was initiated in 1949 (Wingard, 1950) and was continued from 1951 to 1957 by the author.

Spring litters were not found in 1953, 1955, or in 1957, and determination of the age of barren females under these conditions presented difficulties, where nipple characteristics were involved. Case-history records of tagged individuals indicated that some females lost their litters before the young began to nurse. The nipples remained so small in these individuals as to place them in a doubtful age group or in the subadult age group, when judged on the basis of nipple size. These adult females with abnormally small nipples presented even greater difficulties than generally was the case in border-line adult males. In years when the mast crop was poor, squirrels were down in total body weight by late winter: Squirrels bearing eartags of previous years weighed no more than normal for subadults. A more reliable aging criterion was needed, and during the course of this investigation a new method was discovered. The purpose of this paper is to describe a technique for aging gray squirrels by means of tail-pelage characters as well as other known aging techniques.

Previous Work

Age criteria for fox and gray squirrels have been found to include color and condition of the nipples and scrotal sac (Allen, 1943), the fullness and shape of the tail (Brown and Yeager, 1945), and combinations of these along with weight (Allison, 1953; Uhlig, 1955). X-rays of the feet have been proposed (Petrides, 1951), but the method is difficult to carry ont in the field (Flyger, 1952), and previous workers have been unanimous in their estimates of the inadequacy of available field techniques, particularly those for aging males.

[1]Paper No. 85 of the Pennsylvania Cooperative Wildlife Research Unit and the School of Forestry of the Pennsylvania State University; authorized on May 7, 1957, as Journal series No. 2147 of the Agricultural Experiment Station, The Pennsylvania State University, University Park, Pennsylvania. The writer expresses his appreciation to William A. Creed, Research Assistant, who used and tested this aging technique while conducting squirrel studies in Cameron County, Pennsylvania, in 1955 and 1956.

AGE CLASSES

Previous workers have referred to age classes in squirrels as juveniles and adults. This classification is satisfactory only for fall months—September through October.

Based on experience with 671 gray squirrels over a 7-year period, I found it practical to classify squirrels under 6 months of age as juveniles and those 6 to 16 or 18 months of age as subadults. True adult characters appear at about 16 to 18 months of age. Squirrels born in March have assumed subadult characteristics by the following November in Pennsylvania. At this season and following it, aging becomes confusing and subject to error when conventional methods are used, owing to intergradations with characters found in adults. By mid-November, when fall foods are abundant, many spring-littered squirrels are approaching or equaling normal weights and sex characters found in adults. But the late-summer- and early-fall-littered squirrels retain juvenile characters over winter, especially in years when food is scarce. My conclusions are based on aging 310 adults and 141 young of the year in live-trapping operations during the late winter and spring months from 1951 to 1957, and on handling 220 gray squirrels that had been bagged in the fall hunting seasons during the same years.

PELAGE PHASES

There are two distinct phases in the pelage during a season—the summer and the winter coats.

The fall molt.—All age classes of the gray squirrel undergo a fall molt. In Pennsylvania it starts in October and is completed by early November, but occasional individuals show signs of this molt on the flanks and hind legs in the last week in September. In West Virginia, Uhlig (*op.cit.*) reported that the fall molt occurred in October. The fall molt apparently is earlier in Great Britain, since Shorten (1951) observed that the young from spring litters begin to molt the body fur starting in September.

The replacement of the summer coat begins on the posterior parts of the body, including the flanks, hind legs, and rump, and progresses forward. The shoulders, lower forelegs, neck, and head are the last parts to develop the heavy winter coat. Shorten in England and Roecker (1950) in New York described a similar pattern of hair replacement in the fall molt of the gray squirrel. The tail undergoes very little, if any, appreciable molt in the fall. The tail pelage of spring-littered squirrels becomes longer as winter approaches; short appressed hairs appear along the lower one-third of the tail bone, but the texture of the tail, fullness, and color patterns, are similar to those of late-summer litters.

The winter coat is heavy, sleek, and without doubt, the most attractive pelage of the year. All markings and color have attained their greatest intensity at this season. In the northern gray squirrel (*Sciurus carolinensis pennsylvanicus*) this is the time of the year when its subspecific markings are prominent. These markings become indistinct or absent in the summer coat; and I have found that specimens collected in summer for taxonomic purposes may lead to confusion and doubtful determinations.

The spring molt.—Trapping records from 1951 to 1957 in central Pennsylvania revealed that the winter pelage remained unchanged into late April in some squirrels. Shedding appeared first on the head, especially around and between the ears after April 25, but there were just as many others examined that indicated no signs of shedding before May 1. A squirrel most advanced in the normal spring molt, for example, was No. 780 (a subadult female) taken on April 29, 1955. Pelage on its cheeks, the region around its ears, throat, chest, lower forearms, and its ventral region was in the process of being replaced by the newly developing summer coat.

The spring molt proceeds in reverse of the pattern followed in the fall molt—hair replacement beginning on the head and progressing posteriorly. The tail pelage sheds toward the later stages of this molt, and may not be completed for some time after the summer coat has appeared on the body. Since there is considerable delay in

the start of the spring molt among individuals, the summer coat may not be completed in a population before early to mid-June. Roecker (*ibid.*) reported that by May 26 in New York State the spring molt in gray squirrels is almost completed to the rump.

Abnormal or premature loosening and loss of hair on the tails, ventral regions, or shoulders were encountered occasionally by early April. These cases were associated with individuals known to have carried heavy infestations of tail mites (*Haemogamasus ambulans*). Heavy infestations of fleas may also cause hair loss by early April. In other cases dandruff-like conditions caused premature shedding of the winter coat. This premature shedding is distinct in that loss of hair is spotty, it does not follow a pattern, and these bare or thin spots in the coat are not immediately replaced by the new hair. In the normal spring molt short hairs appear under the dense winter coat, gradually loosening it as they grow in length.

Young squirrels of the previous season lose their subadult identity when their tails have completed the spring molt. The resulting new pelage of the tail now assumes the coarseness, color pattern, and fullness characteristic of adults.

AGING CRITERIA BASED ON TAIL-PELAGE CHARACTERS

Tail-pelage Structure and Color

Structure and appearance.—There are two types of hairs in the tail pelage—uniformly long primary hairs, which comprise the basic framework, and shorter secondary hairs that add to its bushy appearance. The longer primary hairs develop laterally from the sides of the tail bone, imparting a characteristic flattish appearance to the tail. Shorter secondary hairs develop along the dorsal side, but these do not extend to the tail border. Shorter secondary hairs on the ventral side are sparse or absent in young of the year, while in adults these hairs are developed but are closely appressed along the tail bone, giving this side of the tail a relatively flat surface.

The first most reliable and dependable criterion for aging is found in the secondary pelage on the lower tail surface in gray squirrels. In juveniles the shorter hairs are absent along the lower side of the tail bone, while in subadults the short appressed hairs are present on the lower or proximal one-third of the tail bone (Fig. 1: 3 and 4), and the tail bone is conspicuous for two-thirds of its upper or distal length. A change occurs following the first tail molt. Short appressed hairs develop, lying flat against and along the full length of the ventral surface of the tail bone. These appressed hairs obscure the outline of the tail bone and are characteristic of adulthood in both sexes (Fig. 1: 1 and 2).

Tail pelage may be coarse or silky in texture, depending on age. For convenience in recording aging data, tail appearances have been classed as (1) light—flat, thin, and silky, (2) medium, and (3) heavy—well furred on both dorsal and ventral sides, with appressed hairs lying along the central ventral region of the tail.

The outline of the tail has been reported by Brown and Yeager (*op. cit.*) as being useful in aging squirrels. This character is extremely variable (Fig. 1: 1, 2, 3, and 4), and there is great variation between sexes, between individuals, and between the tails of living squirrels and those that have been shot. In live animals, their resistance to handling often produces a distorted outline and shape to the tail. In general outline, the sides are parallel in young of the year and in about 60 per cent of all adults, but the tail lengths are variable. Adult males are more likely to have long tails with parallel sides than is the case in females, but this is not a consistent rule.

Pelage color and markings.—The second most important character as an indicator of age is the color and markings of the primary hairs on the ventral surface of the tail. When one examines this surface, white-tipped hairs appear as a white band paralleling the outer lateral border of the tail and abruptly joining a narrow black band that forms the inner-edge border of the tail (Fig. 1: 1–4). The remainder of each hair, comprising

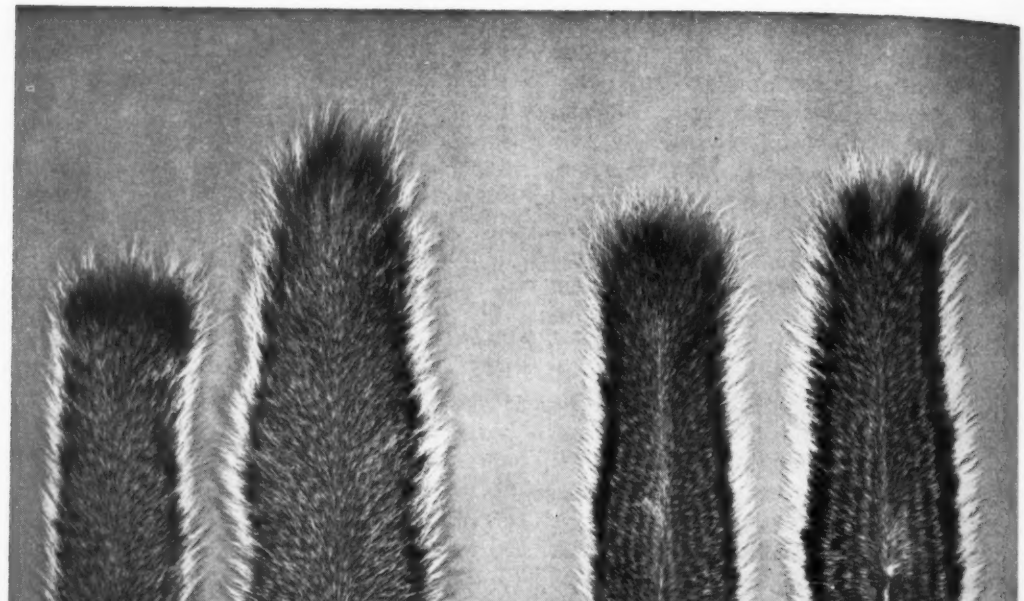

FIG. 1. Tails of gray squirrels showing ventral views. Tails *1* and *2* are from adults tagged in previous years. Dark lines or bars are obscure, and the ventral surface of the tail bone is completely masked by a covering of secondary appressed hairs. Tail *3* is from a summer juvenile, while tail *4* is from a spring subadult. Note the presence of three narrow dark lines in *3* and the presence of two prominent dark bars in *4*. The outline of the tail-bone region is conspicuous in tails *3* and *4*. Specimens were taken during the November open hunting season. Sexes are: (*1*) male, (*2*) female, (*3*) female, (*4*) male.

about three-fourths of its total length, is reddish brown or grayish brown flecked with a dark pigment. Within this reddish brown region of the tail pelage there are two, sometimes three, narrow dark bars or lines running through the brownish pigment parallel to each side of the tail bone. The color intensity and continuity of these dark lines give a clue to age (Fig. 1: 3 and 4).

Tail-pelage Characteristics and Age Classes

Tail characteristics of juvenile and subadult squirrels.—The first step is to note the presence or absence of short appressed hairs along the ventral side of the tail bone. In late-summer litters, these hairs are absent, and the outline of the tail bone is prominent. In spring-littered squirrels of the year, short appressed hairs about one-half to three-fourths inch in length are present on the lower region of the tail bone, obscuring it and forming a narrow line of fur along its ventral side for scarcely one-third of its total basal length.

The two or three dark bars through the

broad band of reddish brown tail pelage, curving around the tip of the tail and meeting the bars from the opposite side, are also characteristic of these age groups. The dark bars are continuous and are easily followed as unbroken narrow dark lines. They are most conspicuous in the medial region of the tail. Ranging from one-eighth to one-fourth inch in width, they become less distinct near the tip and near the base of the tail. Thus, the mid-tail region is most diagnostic.

The sparsity of appressed hairs along the tail bone and the prominence and continuity of the two or three dark lines running along each side of the tail (Fig. 1: 3 and 4) characterize squirrels of the year—juveniles or subadults.

Tail characters of adult squirrels.—In adults, tracts of appressed hairs three-fourths to one and one-fourth inches long have developed along the ventral side of the tail bone, completely obscuring its outline. These hairs radiate out over the lower surface of the primary tail pelage, obscuring the parallel bars or lines so characteristic of juveniles or subadults as shown in Fig 1: 3 and 4. The development of appressed hairs covering and obscuring the lower surface of the tail bone is a constant and dependable criterion of adulthood.

The dark lines or bars paralleling each side of the ventral surface of the tail in young of the year are less prominent in adult squirrels, having become broken and interspersed by the tannish pigment that becomes more intense in adulthood. In adults these bars or lines may show only as dark splotches, giving this inner region of the tail a mottled vermiculate appearance. This character is less dependable than the constant prevalence of secondary hairs along the tail bone. But when both are compared, one against the other, they are the most reliable characters by which to determine age.

DISCUSSION AND CORRELATION OF AGE

The secondary, appressed pelage along the ventral surface of the tail bone and the prominence of dark parallel lines in primary hairs take the guessing out of doubtful cases, and enable the beginner to have more confidence in aging. Creed (1957) reported that about 90 per cent of all squirrels could be aged by this method. Students are able to pick up the technique in one trip afield when squirrels are being handled, aged, and eartagged. But the worker should note condition of sex organs and body weights as additional evidence of age to add to the over-all accuracy of aging all squirrels handled. It was found most reliable and less confusing to examine the tail-pelage characteristics first for age. This evidence, when properly interpreted, serves as the chief criterion when all other known characters fail.

The greatest demand, or need, for aging criteria for squirrels comes in the fall months during bag-checking operations. At this season one will encounter three age groups—juveniles, subadults, and adults. Weights and tail-pelage characters readily distinguish the late-summer-littered squirrels. In subadults, weights and nature of sex organs are often of little value, since they may equal those of adults. But one should, nevertheless, record characteristics of sex organs or body weights when aging gray squirrels by tail-pelage characteristics.

The investigator had ample opportunity to test aging criteria during this study. Old squirrels, tagged in previous years, when recaptured in 1954 and 1955, for example, made up 41.5 and 40.7 per cent of the spring population. A careful note was kept of body weights and tail pelage, nature of sex organs, and characteristics of mammary glands, whenever these old squirrels were recaptured in later years. Tagged squirrels that repeated in subsequent years were: 11 in 1951, 11 in 1952, 23 in 1953, 39 in 1954, 31 in 1955, and 21 in 1957, making a total of 136 squirrels known positively to be adults. An occasional adult female tagged in previous years would reveal nipple characteristics of subadults. All males in good food years would reveal enlarged testicles. But in 1957, a very poor food year, no males, regardless of age, showed enlarged testicles, and no females were lactating or gravid.

Tail pelage was the only character that remained constant through the so-called lean and fat years.

SUMMARY

The development of a tail-pelage aging method has revealed that young gray squirrels fall logically into two age groups—juveniles under 6 months of age, and subadults 6 to 16 or 18 months of age. Upon reaching 16 to 18 months of age, squirrels have acquired characteristics in tail pelage typical of adults.

Gray squirrels undergo two molts in body pelage each season. The summer coat begins to shed by late September and is usually completed during October in Pennsylvania. The spring molt may start in late April and is completed by mid-June. The fall molt proceeds from the posterior regions of the body forward to the head. In the spring molt, the process is reversed: shedding starts on the head and progresses posteriorly. Shedding of the tail pelage occurs during the late stages of the spring molt.

Spring-littered young of the year have attained body weights and sex characters comparable to those of adults by mid-November. Aging at this season and later becomes complicated when conventional methods are used. But the tail pelage reveals constant characters, separating juveniles from subadults, or subadults from adults.

Juvenile and subadult age groups have two, sometimes three, dark lines running through the reddish brown primary hairs of the tail. Short appressed hairs are absent on the tail bone of juveniles, but are present on the lower or proximal one-third of the tails of subadults. In adults, the tail bone is obscured by appressed secondary hairs that radiate out over and partly obscure the long primary hairs of the tail. The lines or bars so prominent in young of the year have become weakened in color intensity, discontinuous, and obscure in the tails of adults.

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AN EVALUATION OF RUFFED GROUSE DRUMMING COUNTS[1]

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Wisconsin has about 16,000,000 acres of woodland inhabited by ruffed grouse (*Bonasa umbellus*). To establish intelligent hunting regulations, it is necessary to know the status of the grouse population on this large wooded area. With this objective in mind, the Wisconsin Conservation Department has used a state-wide winter flush-count index since 1950, and state-wide spring drumming counts since 1951, to estimate changes in grouse numbers. This paper describes the winter flush-count index and compares the results obtained with the drumming counts. Also described are detailed studies to determine the accuracy of drumming counts on smaller land areas.

Methods

Winter Flush Counts

During February and March each year, game-management personnel of the Wisconsin Conservation Department spend hundreds of hours cruising winter deer range. Since Wisconsin's deer and ruffed grouse range coincide, all personnel engaged in this deer work have been asked since 1950 to tally the number of ruffed grouse flushed, if any, and the time spent in the woods. This gives a bird-flushed-per-hour statistic for following population trends. Table 1 shows this statistic for the six years, 1951 through 1956, for northern and central Wisconsin. The counties where these counts were made are shown in Fig. 1. The winter flush index varies from the well-known King census (Leopold, 1933) in that the flushing distance from the observer is not recorded, and the counts are made under varied weather conditions. Table 1 also gives the number of hours involved in these flush counts for each of the six years.

Drumming Counts

From 7 to 20 ruffed grouse drumming transects are run each year, and the counties in which they are located are shown in Fig. 1. We expected that this coverage would show population trends for this portion of the state. Our methods were adapted from the techniques developed in Minnesota by Petraborg, Wellein, and Gunvalson (1953).

All transects have 15 stops, a mile apart, with a 4-minute listening period at each stop. Transects are run only on clear mornings with wind less than three m.p.h.; they are started one-half hour before local sunrise and completed about one hour after sunrise. Two runs are made on each of the

Fig. 1. Counties from which data were obtained on ruffed grouse drumming (circles) and winter flush counts (cross hatching), Wisconsin, 1951–56.

[1]A contribution from Pittman-Robertson projects W-25-R, W-79-R, and W-13-R of the Wisconsin Conservation Department. The authors wish to express their appreciation to Raymond E. Kyro, John Berkhahn, David Cash, and Frederick V. Holzer for contributing major portions of the field work. Charles W. Lemke assisted in the tabulation of the data. Our appreciation is also extended to Ruth L. Hine and Cyril Kabat for reviewing the manuscript.

general transects, with runs five to ten days apart. The individual run with the higher number of drummings heard is used for the year-to-year comparison. The general transects were begun when cock activity was at a high intensity on sample transects. The relation of starting dates to phenology is given below under "Discussion."

Since individual hearing ability varies considerably, it is desirable that the same observers run the individual transects for which year-to-year comparisons are made. All drumming-count results in this report are based on data obtained by the same observers for transects run in successive years. All runs on the study transects were made by Dorney. Table 1 gives the total number of transects and the drumming index for each of the six years used in this report.

TABLE 1.—WINTER FLUSH COUNTS AND SPRING DRUMMING INDICES FOR THE SIX-YEAR PERIOD, 1951 TO 1956

Year	No. Hours for Winter Counts	No. of Birds Flushed per 100 Hours	No. Drumming Transects Run	Drumming Index
1951	571	64	7	100
1952	617	64	13	109
1953	935	50	18	99
1954	812	30	16	45
1955	1,404	25	20	48
1956	1,053	37	18	63

A special 3-year test of the drumming-count technique was started in 1954 on a study area along State Highway 27 in Rusk and Sawyer counties by Dorney. This special study was designed to answer the following questions:

1. Can drumming counts provide an accurate index of population change from year to year?
2. Do some cocks remain "silent"—that is, not drum? Does this percentage of silent cocks vary from year to year?
3. Is the average time interval between drummings constant from year to year?
4. Does population density affect the time interval between drummings?

Our procedure for exploring the above questions was as follows: Six to eight circular plots were laid out along the Highway 27 drumming transect. The centers of these plots were some of the established listening points for drumming stops, specifically, stops 1, 4, 5, 6, 8, 11 in 1954; and in 1955 and 1956, these same six plots were used, plus stops 12 and 15. We sampled only this number of plots due to man-power limitations. Each plot had a radius of 1,350 feet (about ¼ mile) and included about 132 acres. The number of cocks on each of the six or eight plots was determined by both direct searching for all drumming logs three or more times in April and May, and by following the drumming sound to locate birds. In addition, all cocks were caught in mirror traps (Tanner and Bowers, 1948; Dorney and Mattison, 1956) and banded, thus enabling us to distinguish the presence of more than one bird where territories were close together. Banding was also helpful in establishing the presence of cocks that rarely or never drummed. Very few males were missed using this searching and banding technique, as demonstrated by the absence of unbanded adult cocks, 2 or more years old, in subsequent years of trapping. Between 3 and 8 drumming counts were made during April and May on the transect (along which the plots were located), using all 15 stops, during April and May. So as to make the drumming data from this study comparable to that of the state-wide transects, it was necessary to segregate the two runs made during the period in which the state-wide transects were run. The higher count of the pair was then used for the technique evaluation. In addition, by knowing the exact location of males on the eight plots, it was possible to tally whether or not a particular cock drummed, and how often, during the 4-minute listening period. This gave us detailed data on drumming that were needed for this evaluation. We assumed that the six to eight plots were representative of the 15 stops on the transect.

To help study the effect of population density on drumming activity, a single drumming transect was also run through our population study area in the Town of Cedar Rapids, Rusk County, in 1955 and

1956. This area was known to have a considerably lower population density than the Highway 27 area. Here, all 15 transect stops were used as centers for ¼-mile-radius plots, in comparison with the six and eight plots on Highway 27.

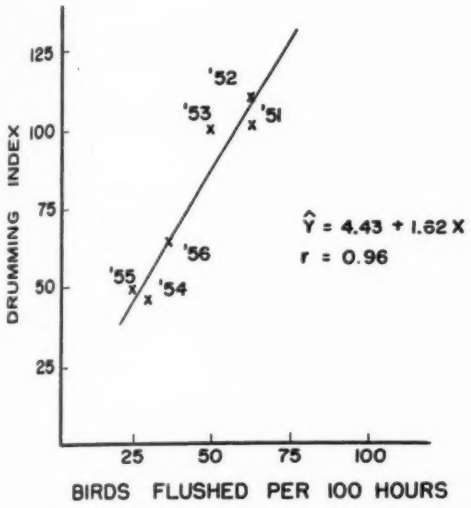

FIG. 2. Regression of drumming index on winter flush rates of ruffed grouse, Wisconsin, 1951–56.

RESULTS

Fig. 2 shows the correlation between the winter flush counts made in February and March and drumming counts obtained in April and May of the same years, 1951 through 1956. The correlation coefficient is 0.96, showing a close relationship between these two independent methods for estimating breeding grouse populations. The 95 per cent confidence limits of this estimate of *r* are 0.66 and 1.00.

Tables 2 and 3 show the results obtained by comparing the drumming counts and actual population levels on the Highway 27 and Cedar Rapids areas. For determination of statistical reliability, these results are, of course, limited, and it will require a great deal more intensive effort of this same type to make a complete appraisal. The standard deviation of the indicated percentage deviations of the ratios is 10 (95 per cent confidence limits of standard deviation 6-42 per cent, with 3 degrees of freedom).

How does cock drumming activity vary from year to year? Table 4 shows the percentage of cocks drumming on six plots when the Highway 27 transect referred to in Table 2 was run. Although the largest percentage of drumming occurred in 1955, the values for the three years do not differ significantly when tested by chi-square. The standard error of the mean percentage is six

TABLE 2.—COMPARISON OF THE ACTUAL NUMBERS OF COCK RUFFED GROUSE WITH THE DRUMMING COUNTS, HIGHWAY 27 STUDY AREA

Year	A Drumming Count	B Actual No. of Males on Plots	Ratio of A:B[1]	Deviation of Ratio from Average
1954	58	25	2.32	– 5%
1955	71	25	2.84	+16%
1956	66	30	2.20	–10%
Average			2.45	

[1] Drummings were recorded at 15 stops while actual males were recorded at only eight stops. (The 1954 count of actual males was made at only six stops, but the count was projected to eight stops for comparison to 1955 and 1956.) These ratios cannot be compared with those in Table 3, since birds were counted on 15 sample plots on the Cedar Rapids area.

TABLE 3.—COMPARISON OF THE ACTUAL NUMBERS OF COCK RUFFED GROUSE WITH THE DRUMMING COUNTS, CEDAR RAPIDS STUDY AREA

Year	A Drumming Count	B Actual No. of Males on Plots	Ratio of A:B	Deviation of Ratio from Average
1955	20	23	0.87	– 5%
1956	35	36	0.97	+ 5%
Average			0.92	

TABLE 4.—PERCENTAGE OF COCKS DRUMMING FOR THE YEARS 1954 TO 1956 WHEN THE HIGHWAY 27 DRUMMING TRANSECT WAS RUN

Date of Transect	Total No. Cocks within Audible Range, 6 Plots	No. Cocks Drumming on These 6 Plots during 4-Minute Period	Per Cent Drumming during the 4-Minute Listening Period
May 12, 1954	21	11	52
Apr. 26, 1955	20	14	70
May 16, 1956	27	17	63

Average percentage of cocks drumming during 4-minute listening period on the 6 plots 62
Average percentage of silent cocks 38

TABLE 5.—EFFECT OF POPULATION DENSITY ON DRUMMING ACTIVITY

Transect	Year	Density of Cocks per 100 Acres of Forest Cover	Ratio of Total Drummings Heard to Birds Drumming in 4 Minutes
Highway 27	1954	2.6	1.2
	1955	2.5	1.4
	1956	3.1	1.2
	Average		1.3
Cedar Rapids	1955	1.2	1.2
	1956	1.8	1.1
	Average		1.2

per cent. The other aspect of cock activity is indicated in Table 5. This table shows the number of times individual cocks drummed during the 4-minute listening period on all 15 listening stops on both study areas, as expressed by a ratio of drummings heard to number of birds drumming. These differences between years and between areas, however, are not statistically significant.

One other aspect of cock activity, the effect of population density on drumming activity, is indicated in Table 5. Many workers have assumed that high breeding populations would tend to stimulate drumming activity. Data in Table 5, however, suggest that the time interval between drummings is insensitive to density differences, at least at the levels worked with in this study.

DISCUSSION

Since drumming counts made on the two study areas successfully provided an abundance index within reasonable limits of sampling error, it is to be presumed that such drumming transects extended to other areas would likewise successfully estimate breeding-season status of ruffed grouse cocks. On this basis the 7 to 20 annual drumming transects have been presumed to show the population trend between years on the major ruffed grouse range in Wisconsin.

In view of the strong correlation of drumming transects with winter flush counts, it is thought to be feasible to substitute these latter counts for the drumming counts, since the winter surveys are carried out incidental to other work and are therefore inexpensive.

However, the years 1951 to 1956 were past the 1949–50 peak of ruffed grouse abundance. Thus, it remains to be seen how winter flush and drumming counts will compare in a "high" year. During peak breeding populations, intraspecific strife could prevent cocks from establishing a territory and drumming; hence, drumming counts could conceivably underestimate the true population.

With the small sampling error suggested by the evaluation of the drumming transect, it is evident that this inventory technique is a very valuable tool in its own right for both research and management. The drumming count is certainly the simplest and easiest method for studying grouse populations on small study areas. Statistical studies by Palmer and Eberhardt (1955) have shown that with a population of five grouse per 100 acres, it is necessary to walk approximately 300 miles of census line to get an estimate of the population within 25 per cent of the true value. Walking these 300 miles would probably require 200 man hours. To locate all drumming cocks by searching on foot for active territories on a 2,000-acre area would require about 500 man hours. According to our evaluation, the drumming transect with 15 stops, run with the use of our procedure, should provide an adequate index of abundance on this same acreage (assuming a ¼-mile audibility radius) with about three man hours, a considerable saving in man power and expense.

Petraborg, *et al.* (*op. cit.*) provided a formula for computing the density of ruffed grouse per acre by using a ⅛-mile radius of audibility and the number of drummings heard per listening stop. By using a two-way radio, we found that Dorney typically could hear ruffed grouse drumming at a distance of about one-fourth mile in flat wooded country, when there was no wind. On one occasion, a bird was actually heard 2,500 feet away on a clear, quiet morning when the observer faced the drumming

bird. Hardy (1952) also used a ¼-mile audibility radius for computing spring density of cocks in Kentucky.

The radius of audibility is a critical measurement, since in computing area the radius is squared. Thus, a circular plot with a ⅛-mile radius would be 31 acres in size and a plot with a ¼-mile radius would contain 125 acres. We believe that the safest approach for converting drumming-count data into birds per acre would be for the same observer to run drumming transects through an area of known population density for a period of years. Then a drumming total could be directly compared to a known density of cocks. This would eliminate the need for using a radius of audibility.

Hungerford (1953) used the anthesis stage of willow catkins as a phenological indicator for determining when to begin running drumming transects. According to our experience, in years with early springs, a sharp peak of drumming may occur before the anthers reach this full development. A count made during this sharp peak of drumming would overestimate the comparative population. We have avoided this overestimation by starting our state surveys when the first willow leaves start to develop, or May 1, whichever occurs first. The first willow leaves ordinarily develop 2 to 4 days following the mature willow catkins. Thus, we are starting our counts a few days later than Hungerford (*op. cit.*) has recommended. The May 1 date is necessary for use in late springs, since we found that ruffed grouse will reach a drumming plateau in these years, even though the willows will have shown no leaf development by this date. No counts should be made after the major forest trees leaf out, since audibility is reduced by leafing. In most years there is about a seven- to fifteen-day plateau when these counts can be made. In an average spring, about four suitable mornings will be found in this period. This means that one man can generally make two runs on two different transects in an average spring.

Some comment should be made about the so-called "silent cocks" (*see* Table 4). In 1955 a cock two years of age or older was trapped on a log that had a few old droppings present. We were very much surprised to catch the bird, since we had never heard him drum nor had we flushed him near the log. The following spring (1956) he was retrapped on the same log and drummed actively throughout the months of April and May. The reason for his inactivity in 1955 is unknown. Other cocks were noted to drum in April but not in May, and vice versa. In some cases a drumming cock that was active in April would be silent one or two mornings during the first part of May, but would drum frequently during the rest of the season. Possibly this coincides with the receptive period of the hen, with the result that the cocks spend time with her and do not drum. No doubt a multiplicity of reasons account for the "silent" cocks that are not drumming when the transects are run at the so-called peak of drumming by ruffed grouse.

SUMMARY

Counts of the numbers of ruffed grouse flushed during routine cruising of deer wintering areas in February and March provided a simple, inexpensive, but apparently reliable, state-wide census technique, as shown by a correlation coefficient of 0.96 between these counts and state-wide spring drumming-count indices.

To test the accuracy of the drumming-count technique, the number of cocks per acre was determined by locating all active territories on two study areas. Drumming transects run for a period of years through these areas of known population density showed that the standard deviation of the drumming-count indices on these transects was ten per cent. Errors other than of the subjective type in the drumming count can result from three factors: a difference in the percentage of cocks that drum, a variation in the time interval between drummings, and the population density of cocks. However, these errors appeared to be unimportant on our two study areas over a three-year period. We therefore conclude that the drumming count is a simple and efficient

method for obtaining indices of breeding populations of male ruffed grouse.

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TOXIC ACTION OF HEXAVALENT CHROMIUM ON LARGEMOUTH BASS[1]

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Investigations of the toxicity of various metals to fish have been reported by many workers, and the literature has recently been reviewed by Doudoroff and Katz (1953). Most of the data reported have been the results of short-term studies of acute cases and generally have dealt very little with the aspects of chronic toxicity. The data on the toxicity of chromium indicate that hexavalent chromium is not toxic to fish when present in water at a concentration of 20 mg. Cr/1. or less. Whether prolonged exposure to nonlethal levels of chromium has any effect on the normal physiology of fish is not known at present. Our experiments were designed to determine the median tolerance limit of chromium to largemouth bass (*Micropterus salmoides*) and then to expose fish to about one-half this value to determine if any changes in the fish resulted.

MATERIALS AND METHODS

The bass were supplied by the Michigan Conservation Department and were delivered in two lots of approximately 200 fish each. Fish were transported from the hatchery in October and in January and were kept in concrete tanks indoors prior to use in the laboratory. They had been kept in ponds at the hatchery and were in good physical condition at the time of arrival. In the laboratory they were fed minnows for the most part; however, a few were fed fresh hamburger. During the course of the experimental period, none of the fish were fed.

To determine the median tolerance limit of chromium, the bioassay procedure proposed by Doudoroff, *et al.* (1951) was used with the following modifications. The fish were kept in aerated aquaria equipped with air-lift filters. A previous check had shown that the filter (glass wool and gravel only) and aeration did not alter the chromium content of the water and, since the water was aerated and filtered, more fish were kept per volume of water than was recommended. These modifications were believed

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not to have interfered with the validity of the results. It was also believed that the data should be comparable to results of others obtained by the bioassay procedure as proposed.

All experiments were carried out under constant illumination in a constant-temperature room. Fish were kept in tap water at 20°–21°C., the water having a total hardness of 334 mg./l., phenolphthalein alkalinity of 6 mg./l., total alkalinity of 206 mg./l. (as $CaCO_3$), and a *p*H range of 8.5 to 8.8. The chromium compound used was K_2CrO_4 in all experiments, and data are presented as mg./l. of hexavalent chromium.

The oxygen consumption was measured, using the experimental procedure proposed by Fromm (1957). A slight modification of the Winkler procedure for the determination of dissolved oxygen was necessary due to the interference of chromium in the water. Samples were obtained in a syringe and the excess water expressed down to the 8-ml. mark. Four-tenths of a ml. of 20 per cent $BaCl_2$ was added to precipitate the chromium as barium chromate. Then the $MnCl_2$ and alkaline azide–KI solutions were added in the usual manner. The manganous hydroxide precipitate was dissolved with 0.4 ml. of concentrated ortho-phosphoric acid and the contents expressed into a plastic centrifuge tube. The samples were centrifuged at 3,200 r.p.m. for five minutes to separate out the barium chromate precipitate, after which exactly 5 ml. of the supernatant were used for the iodometric titration. Appropriate correction for dilution was made in calculating the dissolved oxygen in the 8-ml. sample. To validate the $BaCl_2$ procedure for dissolved oxygen analysis, a sample of water from a beaker was taken; chromium was then added to the beaker, and a second sample taken. Analyses of the two samples revealed a difference of less than 1 per cent in dissolved oxygen. This check was repeated several times with the same results.

The chromium content of the water was measured using the method of Saltzman (1952) and a Bausch and Lomb Spectronic 20 colorimeter. Tissues for histopathological studies were fixed in Bouin's fluid, prepared with paraffin for sectioning in the usual manner and stained with Harris's hematoxylin and eosin.

RESULTS AND DISCUSSION

The 48-hr. TLm (median tolerance limit) of largemouth bass, length 10.6±0.64 cm., weight 11.3±2.7 gm., for hexavalent chromium was 195 mg. Cr/1. In subsequent experiments fish were exposed to 94 mg. Cr/1.

The nonactive, postabsorptive oxygen consumption of four bass weighing 10.5 to 16.1 gm. (average 13.1 gm. wet weight) was 0.095 ml./gm./hr. at 20°–21°C. After the oxygen consumption was measured while they were in clean water, the fish were exposed to 94 mg. Cr/1. (Table 1). A slight increase in the mean oxygen consumption was noted after 2½ hours, followed by a gradual decline to 27 per cent below normal after 68-hours' exposure. After 30-hours' exposure two fish were observed to be turned over, and after 44 hours

TABLE 1.—THE EFFECT OF EXPOSURE TO CHROMIUM ON THE OXYGEN CONSUMPTION OF LARGEMOUTH BASS. THE AVERAGE LIVE WEIGHT OF THE FOUR FISH USED WAS 13.1 GRAMS

Hours Exposed to 94 mg. Cr/1.	No. of Data	Oxygen Consumption (ml./gm./hr.)		Significance of Difference from Control	
		Mean	Standard Error	*t*	*p*
0 (control)	12	0.095	0.002	—	—
2½	12	0.105	0.004	1.97	0.10
23½	17	0.102	0.004	1.64	0.50
49	12	0.074	0.002	6.50	0.01
68	7*	0.069	0.003	6.68	0.01

* Data from a single fish; three fish died between 49-hour and 68-hour runs.

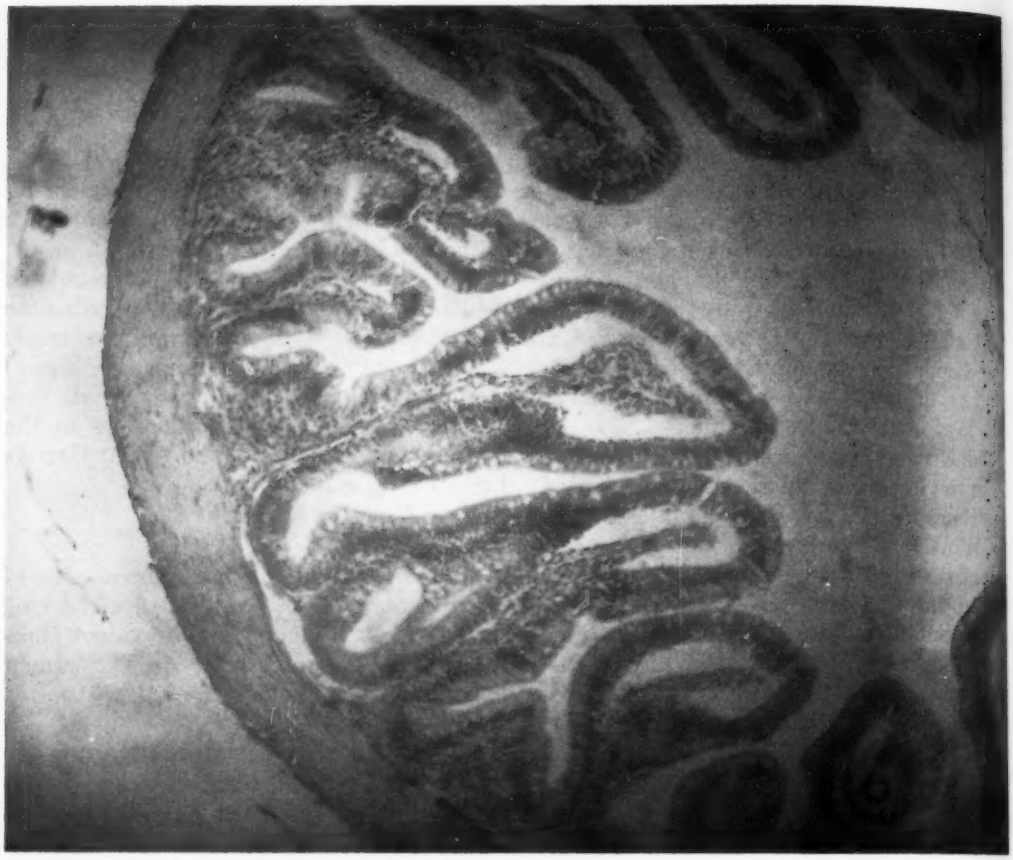

FIG. 1. Section of intestine just below level of pyloric caeca from a normal largemouth bass. H.-E. 5μ, 90×.

flakes and strings of coagulated mucus appeared in the aquarium under the return tubes. After 80-hours' exposure to the chromium, all fish were dead. We were unable to get tissue samples for histological examination from these fish prior to any autolytic breakdown after death; however, other bass exposed to chromium were sacrificed prior to death and samples of gill and intestinal tissue were obtained. The results of a histological examination of gill tissue indicated chromium did not cause any significant alteration in the respiratory epithelium. No change in opercular rhythm was noted in fish exposed to chromium; however, numerous coughing movements, during which the flow of water across the gill membranes appeared to be violently reversed, were observed. The lack of gill damage and the normal opercular rhythm indicate that the oxygen and carbon dioxide content of the blood was not altered to such an extent as to cause stimulation of the respiratory center. This information, coupled with the gradual decrease in oxygen consumption noted upon exposure to chromium, would indicate that chromium caused death to these bass by means other than gill destruction.

It is generally accepted that the death of fish in solutions of heavy metals such as zinc, copper, and lead is caused by precipitation of mucus secreted by the gills, or damage to gill tissues. A recent report by Kuhn and Koecke (1956) has confirmed the action of some heavy metals on the gills

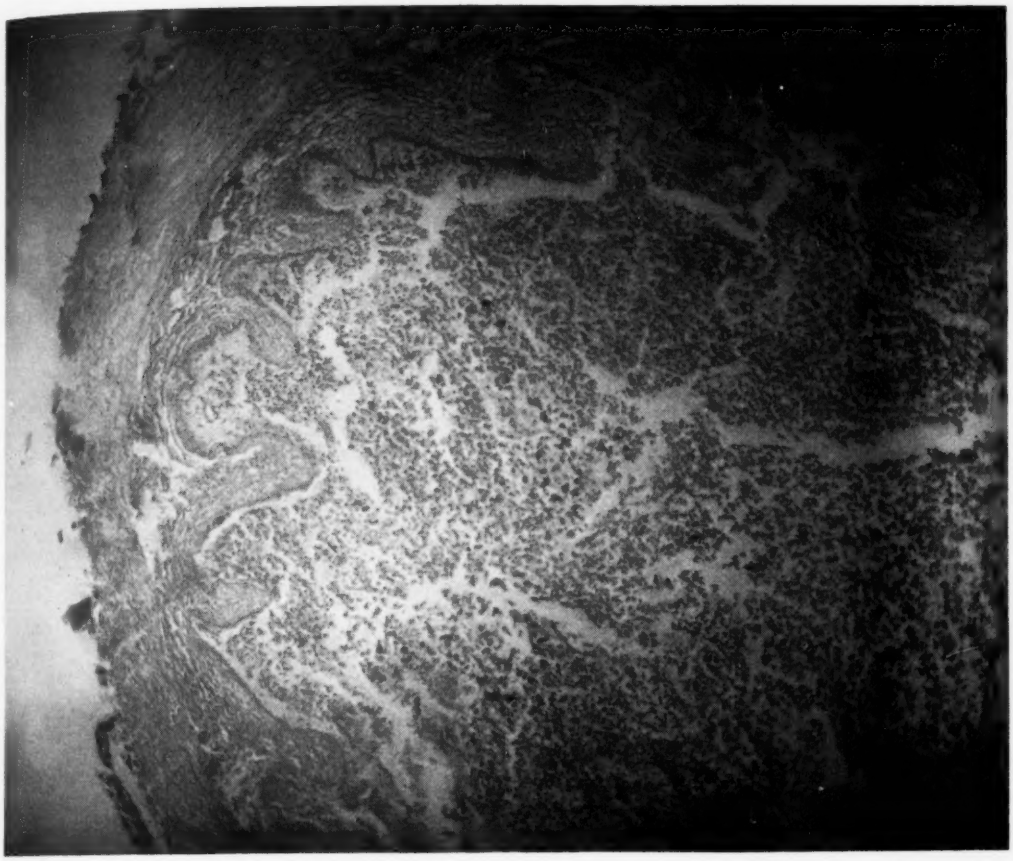

FIG. 2. Section of intestine just below level of pyloric caeca from a largemouth bass exposed to 94 mg. Cr/1. for 36 hours and sacrificed prior to death. H.-E. 5μ, 90×.

and has also indicated that ammonia in toxic concentrations causes death to fish by destruction of the respiratory epithelium. It may be that the gradual decrease in the general metabolism, which we found in fish exposed to chromium, reflects the gradual decrease in cellular metabolism caused by the accumulation of chromium in various tissues. Prosser, *et al.* (1957) have shown that the general metabolism of goldfish and the oxygen consumption of tissue homogenates of brain and muscle but not of liver are reduced by acclimation to low-oxygen concentrations. It is doubtful that the decreased oxygen consumption noted in our experiments was caused by variations in the oxygen level. The dissolved-oxygen content of the water never dropped below 6 mg./1., and this oxygen concentration is undoubtedly above the incipient level and in the zone of respiratory independence, as discussed by Shepard (1955) and Fry (1957).

In addition to the above information, it was observed that exposure to chromium altered the opercular movements of these largemouth bass. Several hours prior to death all experimental fish exhibited coughing movements which were separated by 7 to 13 normal opercular movements. The exact significance of this coughing reflex is not known. Apparently similar opercular reflexes have been observed by Bijtel (1947), who states that these coughing movements are probably associated with cleaning out of the gill passages.

Coagulated strings of mucus appeared

from the anus of each experimental fish prior to death. Histological sections of a 1-cm. portion of the intestine immediately below the level of the pyloric caeca revealed significant changes brought about by exposure to chromium (*see* Figures 1 and 2). In the fish exposed to chromium, there was widespread destruction of the intestinal epithelium, and the intestinal folds were greatly reduced in size. The lumen contained an amorphous mass of debris, and apparently exposure to chromium caused a sloughing off of practically all of the epithelium of the gut. On the basis of the histological appearance of the gut, it is most likely that its digestive function is seriously impaired or lost entirely after exposure to chromium. As subjective evidence to favor this theory, fish exposed to 65 mg. Cr/1. or less for six days, and then returned to clean water, refused food in the form of live minnows even though they were not fed during the exposure period. That chromium from the environmental media reaches the gut as the result of drinking is somewhat doubtful, since fresh-water fish supposedly drink very little water. Our theory is that chromium enters the fish via the gills and is excreted in part by the liver via the bile. In this way the chromium reaches the gut and causes the pathological condition described. Experiments are underway at present to test this hypothesis.

SUMMARY

The median tolerance limit (TLm) of hexavalent chromium to largemouth bass was found to be 195 mg. chromium/1. under the conditions described. Exposure to 94 mg. Cr/1. caused initially a slight but not highly significant increase in the oxygen consumption ($p = 0.05$ to 0.10) of bass followed by a gradual decline to 27 per cent below normal (p less than 0.01) after 68-hours' exposure. Exposure to chromium caused severe pathological changes in the intestine immediately posterior to the pyloric caeca that in all probability completely destroyed its digestive function. The normal respiratory rhythm of bass was not observably altered following exposure to chromium; however, coughing movements which occurred at fairly regular intervals were observed. No significant change in the histology of the gills of fish exposed to chromium was noted. In concentrations that are not acutely lethal, chromium apparently does not kill fish by interference with the respiratory function of the gill.

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THE PRESENT STATUS OF EXOTIC MAMMALS IN THE UNITED STATES

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This paper is designed to supply current information on the status of exotic wild mammals in the United States in more detail than that made available by the broader surveys of de Vos, Manville, and Van Gelder (1956) and Cottam (1956).

In an attempt to secure the most recent information, inquiries were addressed to all state game administrators during April 1957, as well as to numerous other authorities throughout the country, asking about the current status of exotic mammals and their effects, if known, on native plants and animals. Replies were received from all the states. Data thus gathered were supplemented by reference to recent literature and pertinent older writings. Since many years are usually required for introduced species to become established in a new environment, it is necessary to report some information in general terms. This applies chiefly to statements concerning the impact of exotics upon native biota. Differing interpretations and opinions on this subject were encountered even in the few instances where scientific investigations had been made of specific problems.

Commensal and Feral Species

The survey emphasized the well-known fact that commensal rodents are the most undesirable group of exotic mammals in the United States. Black rats (*Rattus rattus*) came ashore with the first settlers, as mentioned by Smith (1612), at Jamestown in 1609. Brown rats (*R. norvegicus*) and house mice (*Mus musculus*) were not far behind (Silver, 1927). Considered as a group, their distribution is now nation-wide, although their numbers have recently been somewhat reduced by widespread use of anticoagulant poisons. Since the survey brought out few direct impacts of commensal rodents upon native wildlife, aside from local or insular situations (e.g., Garden Key, Dry Tortugas), they are not included in the present discussion.

Feral livestock and pets were given much unfavorable comment in this survey, but the results cannot be adequately discussed in this brief paper. The same applies to domestic livestock, the ecological effects of which are ably discussed by Darling (1956). Suffice it to say, the impact of feral species upon native vegetation and both native and domestic animals is attested by numerous local and state laws seeking to restrain or limit them. In the western range states the damage to forage and watering places by feral horses and burros is widely recognized, and the deer and stock-killing propensities of packs of wild dogs are common knowledge in all rural areas. Feral housecats were excoriated, tolerated, and excused, but the present inquiry disclosed only one specific area of serious conflict between feral cats and native fauna. That is on Anacapa Island, in the Channel Islands National Monument, California, where cats have been reported detrimental to a nesting colony of brown pelicans (*Pelecanus occidentalis*).

Fur Animals

Red foxes (*Vulpes vulpes*) were introduced numerous times from England between 1650 and 1750, and may have become naturalized or crossed with our native red foxes (*V. fulva*). The survey did not contribute any new information on the debatable question of whether present fox populations of the east-central and southeastern states are entirely native, a mixture of native and introduced animals, or entirely from introduced animals, as deduced by Gilmore (1946).

Nutria (*Myocastor coypus*) have escaped or been released in many parts of the country since the late 1930's. The period marked the first popularity of nutria fur farming,

with animals being imported from Argentina to farms in a half dozen or more states. Escapes and releases began almost at once. Unconfined nutria were reported or captured during the late 1930's in Colorado, Louisiana, New Mexico, Ohio, Oregon, Utah, and Washington. Although several of these reports are indefinite, at least two antedated the Avery Island, Louisiana, incident which has been several times cited as the first escape in the United States. A fur farm on the Pecos River, in Chaves County, New Mexico, lost about 500 animals during a flood in 1937 (Pickens, *in litt.*). A flood in the late 1930's was also the cause of early escapes in Oregon on the Nestucca River, Tillamook County (Kebbe, *in litt.*).

The large nutria population now existing along the Gulf Coast from Mississippi to southern Texas originated at Avery Island, Iberia Parish, Louisiana, where the animals escaped, during a 1940 hurricane, from the nutria fur farm started by E. A. McIlhenny in March 1938 (Harris, 1956). These animals increased rapidly, and have now spread to suitable habitats along the entire western Gulf Coast, inland in Texas, Louisiana, and Mississippi, and up the Mississippi River to southern Missouri on the west side (Towell, *in litt.*), and to Bolivar County, Mississippi, on the east side (McRaney, *in litt.*). Some of this expansion has been augmented in recent years by intentional releases at various places. Several small coastal colonies, originating independently, are now found in the Mobile Delta area of Alabama (started about 1948); western Florida; on the Outer Banks of North Carolina from Cape Hatteras to a point about 12 miles north (1941 release) and also in Currituck County; and in Back Bay, Virginia. On the West Coast, in addition to Oregon, small groups now exist in Washington, around Lake Washington; and in California, where an escape in Stanislaus County in 1945 was vigorously trapped but still persists (Howard, 1953).

Inland there are a number of small populations, none of which seem to be as vigorous as the coastal groups. There are some along the Grande Ronde River, in Union County, eastern Oregon; a few on the St. Maries River watershed, Benewah County, Idaho (Shaw, *in litt.*); a small colony in Gallia County, Ohio (Chapman, *in litt.*); several small colonies in southern Michigan and the southern part of the "Thumb"; and possibly a few remaining from a release near Fort Knox, Kentucky. Numerous releases and escapes elsewhere seem not to have maintained themselves. However, there is a general lack of definite information, as reported by Petrides and Leedy (1948) for Ohio.

Reports indicate little or no harmful effects from the northern inland populations, none of which are increasing rapidly, and some barely holding their own. Southern and coastal populations, once established, seem difficult or impossible to contain. In that area there are increasing complaints of their damage to vegetation, and their competition with muskrats and waterfowl. Cultivated fields adjacent to marshes often show damage to rice, cane, and other crops. On waterfowl areas, as at Eagle Lake, Colorado County, Texas, the nutrias destroy aquatic vegetation needed for duck food. On coastal marshes of Louisiana and adjoining states the heavy nutria population has destroyed, at least temporarily, large quantities of marsh vegetation upon which many muskrats and waterfowl formerly depended. This condition is especially apparent at the Delta National Wildlife Refuge, Plaquemines Parish, Louisiana (Harris, *in litt.*).

Among trappers there is some sentiment favorable to nutria, despite the difficulty of pelting and low prices for the fur. The 1955–56 catch in Louisiana brought trappers an average return of $1.00 per pelt, as compared to an average of $0.80 for muskrat. The average for the 1956–57 catch will apparently be about the same. Even so, nutria have for the past seven years been the third most valuable fur crop in Louisiana, being exceeded only by muskrat and mink. Income there from nutria in 1955–56 was $418,792, as compared to $1,457,472 from muskrat; $628,562 from mink; and $2,644,986 from all furs (Yancey, *in litt.*).

In spite of these economic values, there is considerable difference of opinion among trappers and wildlife managers as to

whether nutria are desirable. To summarize opinions expressed in the current survey, it is apparent that nutria are an agricultural liability, a detriment to waterfowl, and a possible asset to the fur resources of the country. Factual data upon which to base informed opinions are incomplete, and there is great need for investigations of the ecological and economic relationship of nutria to native fauna and to agriculture. Little is known concerning practicable methods of controlling them.

SMALL GAME

European hares (*Lepus europaeus*) were first introduced into the United States at Jobstown, New Jersey, in 1886 (Silver, 1924). Since then they have been introduced or transplanted into New York (about 1893), Connecticut (shortly before 1920), Massachusetts (late 1920's), and Maryland (about 1940). Contrary to some reports, there is no record of their occurrence in Minnesota (Erickson, *in litt.*). They have been recorded in the past from Pennsylvania, but did not become established. The New Jersey importation also did not persist, although the hares were present sparingly in Middlesex County in 1924. None have been known in the state since about 1947. In Massachusetts the species did not become well established, and it is believed that the few individuals still occasionally reported may be strays from New York. The occasional hares in Michigan are apparently migrants from Canada (Douglass, *in litt.*).

Importations into Connecticut, Maryland, and New York followed a pattern of rapid increase, then a period of heavy agricultural damage, next a decline, and now a stabilization at a comparatively low level where agricultural damage is scarcely noticeable and values as game animals are generally recognized. This sequence is well described for the New York hare population by Dell (1957).

At present the hares are reported from three isolated areas in New York. The largest consists of the northeastern half of Dutchess County and the two southeasternmost townships of Columbia County; another covers the southern border of Montgomery County and into the adjoining edges of the three counties to the south; the smallest area is in west-central Washington County. A few are scattered elsewhere. There is no closed season on them in New York (Dell, *in litt.*).

In Connecticut they are also hunted at all times. They occur in the northwestern portion of the state, where present populations are estimated at from two to four per square mile, as contrasted with 20 to 40 per square mile during the period of abundance about 1927. No complaints have been received during the past 20 years. Hunters annually take from 50 to 200 (Lamson, *in litt.*).

Maryland now has very few European hares, in Kent County, although they were fairly numerous up to 1950 (Vaughn, *in litt.*).

European rabbits (*Oryctolagus cuniculus*) have attracted attention in recent years under the name "San Juan" rabbits. Although many releases have been made since 1952, none have been successful, according to the current survey. Similarly, there are no known naturalizations resulting from thousands of the animals released or escaped for many years from rabbitries and pet pens on the mainland of the United States.

On certain islands having favorable climate and no predators, these rabbits have rapidly become pests. The classic San Juan episode, beginning in 1900, is well documented (Couch, 1929). Another, and little-known, island-pest situation exists on South Farallon Island, about 30 miles west of San Francisco. A third is on Santa Barbara Island, Channel Islands National Monument, California. There the survival of several endemic plants is jeopardized by the rabbits, and strenuous efforts to control the pests are being made jointly by the National Park Service and the Fish and Wildlife Service (Elliott, *in litt.*).

DEER

Red deer (*Cervus elaphus*) are established in the Kentucky Woodlands National Wildlife Refuge, Trigg County, and in the Bernheim Forest, Bullitt County, Kentucky.

It is estimated there are now 66 head, descended from an introduction into the state in the early years of the present century (Mitchell, *in litt.*). In California several escaped or were released from the Hearst Ranch, San Luis Obispo County, but specific information on them is lacking.

Sika deer (*Cervus nippon*) in the wild are apparently confined to one small group on the Chincoteague National Wildlife Refuge, Accomac County, Virginia, and adjacent territory in Maryland. Current numbers are estimated at 60. The writer has heard two versions of this introduction. Dan Trimper, of Ocean City, Maryland, relates that two or three pair were given to his Boy Scout troop in 1923 by a Captain Will Powell. The animals were released on the north end of Assateague Island, Worcester County, Maryland. The other version is that the deer first appeared at about the same place by escaping from a nearby island owned by Sam Riddle. In either event, the deer moved south to the refuge where they now remain most of the time, because the portion of Assateague Island north of the refuge has little favorable environment.

Sambar deer (*Cervus unicolor*) exist in the wild in San Luis Obispo County, California, having come from the Hearst Ranch, but no information is available on their numbers or welfare. The Sambar deer referred to by de Vos, *et al.* (*op. cit.*) in Florida are restricted to a privately owned island (St. Vincent's, near Appalachicola), hence do not fall within the admittedly arbitrary classification of "wild" animals considered in this paper.

Fallow deer (*Dama dama*) are the most widely introduced and apparently the most successful exotic ungulates in the United States. They usually naturalize in whitetail deer habitat and to a certain extent elsewhere, if given considerable initial protection. The comparatively large number of established introductions are listed here, so far as known, with brief comments.

One small release is known from Alabama, made in 1947, in Wilcox County. It is apparently maintaining itself (Sessums, *in litt.*).

In California, several groups have escaped or been released from private estates, but none have prospered too well. The chief releases were: 12 head in Marin County in 1930, now numbering about 60 head; about 20 in Mendocino County in 1937, now increased to approximately 80; and an unknown number dispersed from the Hearst Ranch in San Luis Obispo County in the early 1940's, which apparently have done little more than maintain themselves (Gordon, *in litt.*).

In Colorado a few were released in the late 1920's or early 1930's east of La Jara, Conejos County; another small group in the Cherokee Park area of Larimer County, about 1935; and a third in Rio Blanco County, in 1944, near Buford. It is reported that there are now a total of 50 or 75 fallow deer at large in Colorado (T. L. Kimball, *in litt.*).

Kentucky state authorities introduced fallow deer about 1900, from which came the herd of about 200 now living in Kentucky Woodlands National Wildlife Refuge, Trigg County. In 1956 a permit hunt resulted in removal of 8 (Erickson, *in litt.*). So far as known, the Kentucky herd is the oldest naturalized group of fallow deer in the United States.

Massachusetts introduced several to Martha's Vineyard in 1932. About 150 exist there now, and 10 to 15 are taken annually during the open season (McLaughlin, *in litt.*).

In Maryland, a few animals remain from introductions made between 1920 and 1930 in Worcester County, and between 1935 and 1945 in Talbot County (Vaughn, *in litt.*).

A Nebraska herd, chiefly in Boone County, has been recently reported on by Packard (1955). The original introduction consisted of 73 animals taken by ranchers from the Pioneer Park herd in Lincoln, Nebraska, to the Ray Hall Ranch in Beaver Creek Valley, 20 in 1939, and 53 in 1940. They have spread up and down the valley and into adjoining counties. The present population totals 350 to 400 head. Nine were taken by archers in the 1956 season in Nebraska (Vance, *in litt.*).

Several private herds in New Mexico have spread into adjacent areas, but no information on them was reported in this survey. A small herd of less than 50 has barely maintained itself for the past 12 years in the old Camp Gruber area, Muskogee County, Oklahoma. A few are taken annually by archers (Nelson, *in litt.*).

Axis deer (*Axis axis*) are established in Florida and possibly in Texas. Those in Florida escaped from a pen in Volusia County sometime in the 1930's. Since then they have spread into Flagler, St. Johns, and Duval counties. They are not open to hunting and are no problem (Strode, *in litt.*).

In Texas a number of large ranches on the Edwards Plateau have introduced axis deer, which may have spread to adjoining areas (Landon, *in litt.*).

Hog deer (*Axis porcinus*) were introduced to James Island, Dorchester County, Maryland, about 1922, by the owner of the island. They quickly overpopulated the area, and expanded onto Taylors Island about 1935. It is estimated there are now about 150 on the two islands and the adjacent mainland shore (Vaughn, *in litt.*).

Several ungulates not listed in this paper have been imported by owners of large estates or ranches, particularly in Oklahoma and Texas, but so far as known none have spread outside the original fenced introduction sites. In some cases, the animals have, in effect, become naturalized within the limits of the vast ranch properties where they are confined. The most notable case is that of nilgai (*Boselaphus tragocamelus*) on the Norias Division of the King Ranch, Texas, where five were introduced early in the present century. The herd now contains about 500 head (Landon, *in litt.*).

MISCELLANEOUS BIG GAME

Wild boars (*Sus scrofa*) are established in California, New Hampshire, North Carolina, and Tennessee. Although they are not compatible with ground-nesting birds and are destructive to reforestation and agriculture, the small naturalized groups in this country are tolerated because they confine themselves largely to rough country and have some value as game animals. This value seems to decrease in proportion to hybridization with feral hogs (Shaw, 1941).

The North Carolina–Tennessee group is the largest and oldest, dating from an escape in 1920 from a private preserve near Hooper Bald, Graham County, North Carolina, and now numbering 500 or more in Graham, Cherokee, and Clay counties, North Carolina, and adjoining Monroe County, Tennessee. The annual hunting take is small (42 in Tennessee in 1956), probably owing to the difficulty of hunting wild boars and their limited trophy appeal (Anderson, *in litt.*).

In the Santa Lucia Mountains of Monterey and San Luis Obispo counties, California, there is a small group of wild boars descended from a 1929 escape or release of North Carolina stock that had been placed on the Francisquito Ranch in 1924. Several are regularly taken annually during open season (Gordon, *in litt.*).

New Hampshire has a small population of boars in northwestern Sullivan County which are descended from escapes from Corbin's Park during the 1938 hurricane. They now number between 20 and 40 and are pretty well taken care of by year-round hunting (Carpenter, *in litt.*).

Black buck (*Antilope cervicapra*) have spread beyond their original fenced introduction sites (private ranches) on the Edwards Plateau, Texas, but cannot yet be considered as well established in the wild (Davis, *in litt.*). Some sentiment is expressed for classing them as a legal game animal.

Barbary sheep (*Ammotragus lervia*) were introduced into New Mexico in 1950 by the State Game and Fish Department. There are now between 250 and 350 living in the Canadian River gorges of northeastern New Mexico. They are doing well and were hunted during the open seasons of 1955 and 1956, with a total take of 16 rams (Pickens, *in litt.*).

Barbary sheep are also established in San Luis Obispo County, California, having escaped or been released from the Hearst

Ranch. They are reproducing, but apparently not spreading (Gordon, *in litt.*).

In Texas, Barbary sheep are reported to have spread over portions of the Edwards Plateau, from introductions by individual ranchers. The animals recently released in Palo Duro Canyon have not been there long enough to enable one to tell whether they will become established (W. B. Davis, *in litt.*).

Mouflon (*Ovis musimon*) in California have the same origin and essentially the same status as Barbary sheep.

CONCLUSIONS

Although this discussion deals chiefly with current numbers and conditions of exotic mammals in the United States, as well as their present relations to native plants and animals, it also carries implications regarding the desirability of such introductions. A few of the correspondents who contributed to this survey commented favorably on certain introductions, but the majority felt that benefits were questionable and not sufficient to justify expenses involved. A majority also expressed sentiment against making future introductions without advance study of possible effects. Many correspondents commented upon the desirability of improvement of habitat for native mammals as contrasted to the undesirability of making outlays for importation of exotic mammals.

SUMMARY

Replies received early in 1957 from inquiries addressed to 74 state game officials and other authorities throughout the United States are here combined with references to pertinent literature to provide a detailed discussion of exotic mammals in this country. Space permitted only general discussion of those portions of the replies dealing with feral mammals and commensal rodents. Of other mammals, the survey revealed 15 exotic species now existing and apparently maintaining themselves in this country in a wild state, resulting from not less than 63 introductions. These introductions, dating from about 1650 (1609 for black rats) to 1950, were nearly all made by wealthy landowners and sportsmen. Results have in many cases been negative, or inconclusive. A few introductions appear to be succeeding, and at least one, nutria, is currently succeeding too well. A majority of the correspondents in this survey were unfavorable to further importations.

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NORTH AMERICAN MOOSE TRANSPLANTATIONS AND HANDLING TECHNIQUES[1]

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During the past 75 years, moose (*Alces alces*) have been transplanted to several different areas of North America, and, on two occasions, from North America to New Zealand. The latest moose-transplant operation was conducted in 1953 when moose were trapped in Newfoundland and introduced into Labrador.

Reports have been made of some of the transplants: in Michigan (Hickie, 1943) and in Wyoming (Grasse, 1950), and to New Zealand from western Canada (Donne, 1924). The transplants from Alberta to Nova Scotia, from the Quebec mainland to Anticosti Island, and from Nova Scotia and New Brunswick to Newfoundland, have gone unrecorded, or have been given passing mention in accounts that dealt mainly with other topics (Newsom, 1937; Pimlott, 1953). Trapping operations, for tagging purposes, are being conducted in British Columbia and have recently been reported by Ritcey and Edwards (1956).

The objectives of this paper are threefold: to present in detail the techniques used in trapping and transporting moose from Newfoundland to Labrador; to assemble, and to review briefly, other moose transplants that originated in North America; and to discuss the high mortality that has occurred in some of the trapping and transplanting operations.

Moose Transplantations

Newfoundland to Labrador

The Newfoundland trapping operation was undertaken in 1953 by the Department of Mines and Resources. The objective of the program was to obtain moose for an introduction into favorable areas of southern Labrador (Fig. 1).

The trapping operation was conducted in the Humber Game Reserve, in western Newfoundland, between January and April 1953. During this period 32 moose were captured. Twelve of these, seven cows and five bulls, were finally released at St. Lewis River, Labrador, on June 5, 1953. Of the remainder, ten died during the trapping operation, seven were set free from the trap or the corral, and three escaped either by breaking down the trap door or by jumping over the trap fence (Table 1). The moose were set free for various reasons: Three cows were nervous and were considered unlikely to survive; a cow was released because of a leg infection; a cow captured late in the season was released because lack of snow prevented its being moved to the corral; a cow that calved a short time before the shipment to Labrador became very wild and was released. The one bull freed was old and large, and was considered a handling risk.

Experimental traps were constructed in December 1952. However, the trapping program did not get under way until January 11, 1953. The first moose was trapped on January 21 and the last one on April 4. The moose were crated at the corral on June 3 and released at St. Lewis River, Labrador, on June 5.

[1] Acknowledgments are due H. W. Walters and E. Balsom, of the Wildlife Division of the Newfoundland Department of Mines and Resources, who offered helpful suggestions throughout the Newfoundland trapping operation reported in this paper. The latter designed the single-gate tripping device. A. W. F. Banfield, of the Canadian Wildlife Service, contributed the information on the Alberta-to-Nova Scotia transplant. I. H. Bartlett, of the Michigan Department of Conservation, provided information on the present status of moose in Michigan. J. J. Hickey and R. A. McCabe, of the University of Wisconsin, and L. M. Tuck, of the Canadian Wildlife Service, offered suggestions on the manuscript.

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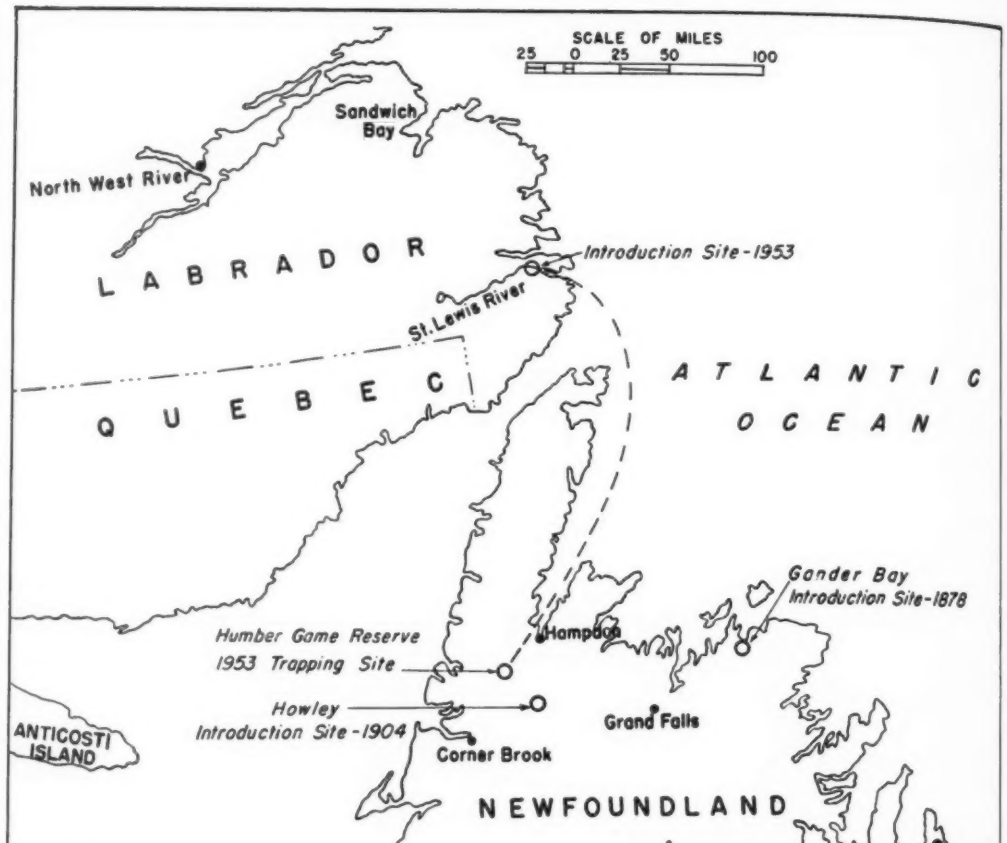

FIG. 1. Province of Newfoundland moose introductions.

The trapping crew consisted of nine men and a cook. This crew handled all the work associated with the operation, including the construction of eight corral traps and the holding corral, and the preparation of the snowmobile roads that linked the various traps with the highway. On completion of the trapping program, the crew was reduced to a cook and four men, who constructed the shipping crates and tended the moose until they were shipped to Labrador.

In planning the operation we adapted many techniques that were developed during the Michigan work in Isle Royale (Hickie, *op. cit.*).

Traps and corral.—Corrals, or corral-type traps, have been used almost exclusively in those moose-trapping operations for which information is available. In the Newfoundland trapping we, too, preferred to build this type because the only materials that had to be transported to the trap site were nails and tools. This type of trap could also be used as a holding pen when snow conditions did not permit moose being moved to the holding corral.

TABLE 1.—RESULTS OF RECENT NORTH AMERICAN MOOSE TRANSPLANTS

Area	Year	Trapped	Transplanted	Deaths	Escaped and Freed
Michigan[1]	1935	16	11	1	4
	1936	71	41	15	15
	1937	40	25	11	4
	Total	127	77	27	23
Wyoming	1934	17	—	17	—
	1948	13	8	4	1
	1950	9	8	—	1
	Total	39	16	21	2
Alberta to Nova Scotia	1947	12	8	4	—
	1948	10	10	—	—
	Total	22	18	4	—
Nfld. to Labrador	1953	32	12	10	10
Grand total		220	123	62	35

[1] Problems were encountered in working out these data, as discrepancies were found to exist in the text, and between the text and the tables published by Hickie (1943). The dates shown are the release dates.

Eight traps were constructed at distances up to 6 miles from the holding corral. Six of the eight traps were double-sectioned, and two were single. The trap dimensions were not standard, but varied with the availability of materials and with the location. The dimensions of the largest double trap were approximately 40 feet by 20 feet, and the dimensions of the smallest were 30 feet by 14 feet. The dimensions of the single traps were approximately 20 feet by 12 feet. The fences of both types were approximately 7 feet high. We found that it was important to place the rails close together, as the moose attempted to force their heads between wide-spaced rails. The double traps required 10 to 15 man-days to construct; the single traps, approximately 6 man-days.

The gate-tripping device that we used in all but one of the corral traps consisted of a simple wood toggle that hung from a horizontal pole (Fig. 2). A length of hay wire extended from the bottom of the toggle and joined, at right angles, a length of picture cord that extended across the trap

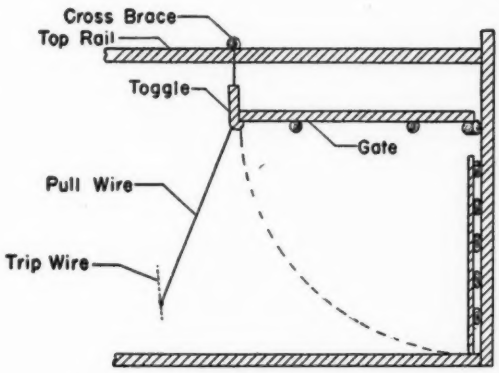

FIG. 2. Single-gate tripping device.

approximately 3 feet from the ground. Pressure exerted on the picture cord was transmitted directly to the toggle and resulted in the door being released. The picture cord was easily broken, eliminating the danger of a moose becoming entangled after it was trapped. This tripping device was ideal for the operation of a single gate but was not easily adapted to the simultaneous operation of two gates.

In one of the single traps that had two gates we operated another type of gate-tripping device (Fig. 3), which permitted simultaneous release of both gates. The mechanism consisted of two triggers, a trip-pole, and connecting lengths of rope and wire that extended from the triggers to the gates. The triggers were centrally located, one on each side of the trap, and approximately 3 feet above the ground. The wire led from the bottom of the gate up over the two top crossbars of the trap and was joined to a short length of rope with a knot on the end. The knot held the rope into the slot of the trigger. When the gates were up, their weight exerted tension on the triggers and held the trip-pole in place. When the trip-pole was removed, the triggers swung up, the ropes slipped out, and both gates swung down. The gates were top-hinged with hay wire. To reduce the danger of injuries, in the case of an animal being struck by a gate, these gates were made of light, dry poles.

The original holding corral had six interconnecting sections and covered an area of approximately one-quarter acre. It was con-

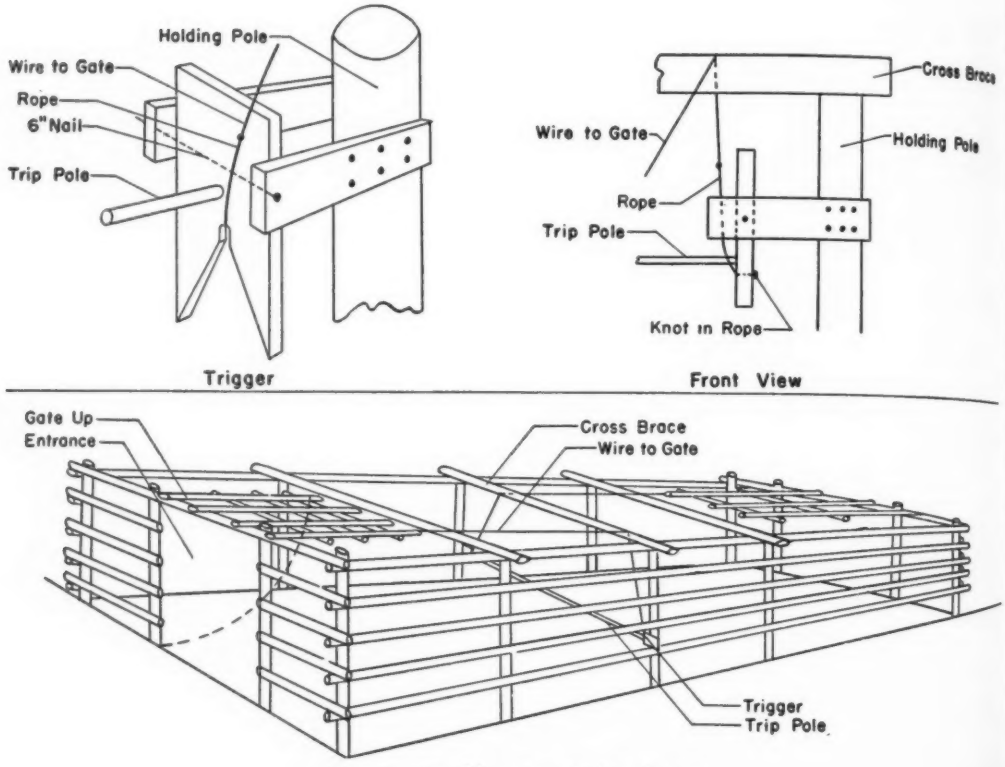

FIG. 3. Double-gate tripping device.

structed of spruce and fir poles and was similar to the traps in appearance. In March a 2-acre extension was added. The fence of the extension was constructed of two tiers of 48-inch farm fencing, and enclosed an area of dense, second-growth spruce and fir.

Baiting techniques.—The area where the trapping operation was conducted was overpopulated by moose, with the result that virtually all palatable deciduous species had been killed by overbrowsing. We attracted moose to the traps by felling large white birch (*Betula papyrifera*), enabling the animals to browse on the branches inside the traps and in the area immediately about them. Balsam fir (*Abies balsamea*) was also cut for bait; however, this species is not so palatable to moose and, therefore, not nearly so effective a bait as white birch.

On Isle Royale, where it appears that browse conditions were even more extreme, balsam fir was successfully used as a bait to attract moose to the traps (Hickie, *op. cit.*). The method of baiting in the 1934–35 operation was to cut down the trees at 40- to 50-yard intervals for distances of more than a mile from the trap. The theory was that once the moose found the trees they would work toward the trap. In the Newfoundland operation we found it unnecessary to use bait more than one or two hundred yards from the traps. When snow became deeper and the moose roamed less widely, we were able to channel them into the baited areas by keeping a snowmobile road open between traps. Moose coming upon these roads tended to move along them in preference to continuing through the unpacked snow. In addition to baiting the area immediately around the trap, we also placed bait inside the traps. Birch branches were hung there in an inverted position from the top rails, and young balsam firs were tied to the rails in an upright position.

In the 1950 Wyoming operation, the moose were on feeding grounds where alfalfa hay was being used as a supplemental food (Grasse, *op. cit.*). Since the moose were accustomed to a hay diet, no trouble was encountered enticing them into the corral with the alfalfa bait. Moose do not normally eat hay when browse is available, and it is doubtful that hay could be used successfully for bait unless the moose previously had acquired a taste for it, or unless starvation conditions existed.

Feeding and watering.—The captive moose were fed on a natural diet, principally of white birch and balsam fir. In preparation for the trip to Labrador, birch saplings were cut along the roadside, the branches were trimmed from the stems and tied in 40- to 50-pound bales of uniform size. The baled browse was kept fresh by placing it in a brook until shipping day. On board ship approximately half the bales were placed in wooden tubs that were partially filled with water. From the fresh condition of the browse on arrival in Labrador, three to five days after it was cut, we judged that browse handled in this manner would remain palatable for at least two weeks.

The simplest method of feeding the crated moose was to slide up the crate door and to place a bale of browse in an upright position inside, tying it to the side of the crate. The moose then fed at will and ate the stems down to short stumps.

Galvanized sheet-iron watering pans were used to provide water for the crated moose. The pans were 7 inches deep and had top dimensions of 10 inches by 7 inches, tapering to 10 inches by 5 inches at the bottom. They hung by galvanized strap hooks at the head of the crate.

Crates.—During the trapping operation we used a double-drop-door crate, the inside measurements of which were 2 feet wide, 6 feet high, and 8 feet long. This crate was of the same dimensions as the ones used in the Isle Royale operations (Hickie, *op. cit.*). For transporting the

FIG. 4. Moose entering holding corral.

moose to Labrador the crate width was increased to 2½ feet for all adult animals. A year later, when we air-freighted a yearling moose to Holland, we reduced the dimensions to 2 feet by 5 feet by 7 feet; this crate was barely high enough for this 14-month-old animal.

The sides of the crate used to transport moose from the trap to the corral were lined with masonite to a height of 2½ feet. This afforded a smooth surface on which an animal could not hook its feet during the tilting of the crate, described in the next section.

Crating at the trap.—During the 1935–36 Siskiwit Bay operations on Isle Royale, difficulties were encountered in crating moose at the traps. Two different methods were used, one was to confine the moose to a runway and then force it into the crate. The second method, and the one finally adopted, was to bait the moose into the crate (Hickie, *ibid.*). We attempted the runway system with the first moose we crated and encountered great difficulty in getting the animal into the crate. Thereafter we simply backed the sled, on which the crate sat, to the trap gate and opened the gate of the trap and the door of the crate. The members of the party then gathered on the fence around the other sides of the trap and waved their arms and shouted. Invariably, within a short time the moose stepped up and entered the crate. A man standing on top of the crate, concealed by the door (Fig. 4), then dropped the crate door. To prevent the moose from being injured by kicking the crate or being thrown around on the trip from the trap to the corral, we adopted another Isle Royale technique of forcing the moose to lie down (Hickie, *ibid.*). As soon as the moose entered, the crate was tilted to an angle of approximately 40° against a prepared framework. The animal could not remain on its feet and immediately lay down. Strips of canvas were then pulled through the openings in the side of the crate, at a height of 2½ feet, and were nailed securely to the bottom of the crate on each side. The crate was then returned to an upright position. The moose, although in a normal lying-down position, could not regain its feet until the canvas was removed at the corral. In the 1936–37 Isle Royale trapping, a special crate was constructed with one side that folded down to make a low false top that prevented a moose from getting to its feet (Hickie, *ibid.*).

A Bombardier snowmobile was used to transport the crated moose on a sled from trap to corral (Fig. 5).

Crating at the corral.—During the Isle Royale operations three methods of crating at the corral were used: (1) forcing the animals through a box trap into a crate, (2) baiting the crate and dropping the door after the animals entered to feed, (3) driving the animals through a narrow runway and into the crates through a series of three swinging gates (Hickie, *ibid.*).

We realized, from reading the Isle Royale account, that crating relatively tame moose at a large corral could be time-consuming. We faced the necessity of making a quick transfer of the animals from the corral to a ship already waiting at the loading port. Hickie (*ibid.*) reported that the moose became excited when the runway method of crating was used. However, we decided that if a very narrow runway was used, this method offered the best possibility for a combination of speed in loading and a minimum of disturbance. In the corral design we had included two connecting runways. The first runway, approximately 6 feet wide, joined the various sections of the corral to the narrow loading runway which was 2 feet wide, and which led directly to the loading ramp. The earth bank in front of the loading ramp was cut away so that the floor of a 3-ton truck's rack was level with the end of the loading chute.

During the loading operation two animals were kept waiting in the wide runway; when a truck came to the ramp they were driven, one at a time, into and through the narrow runway. Since they could not turn around in the narrow runway they went directly into the crate. There were no complications, and no forcing was required. We were able to load a truck with its complement of two crated animals within ten minutes, which included moving the truck

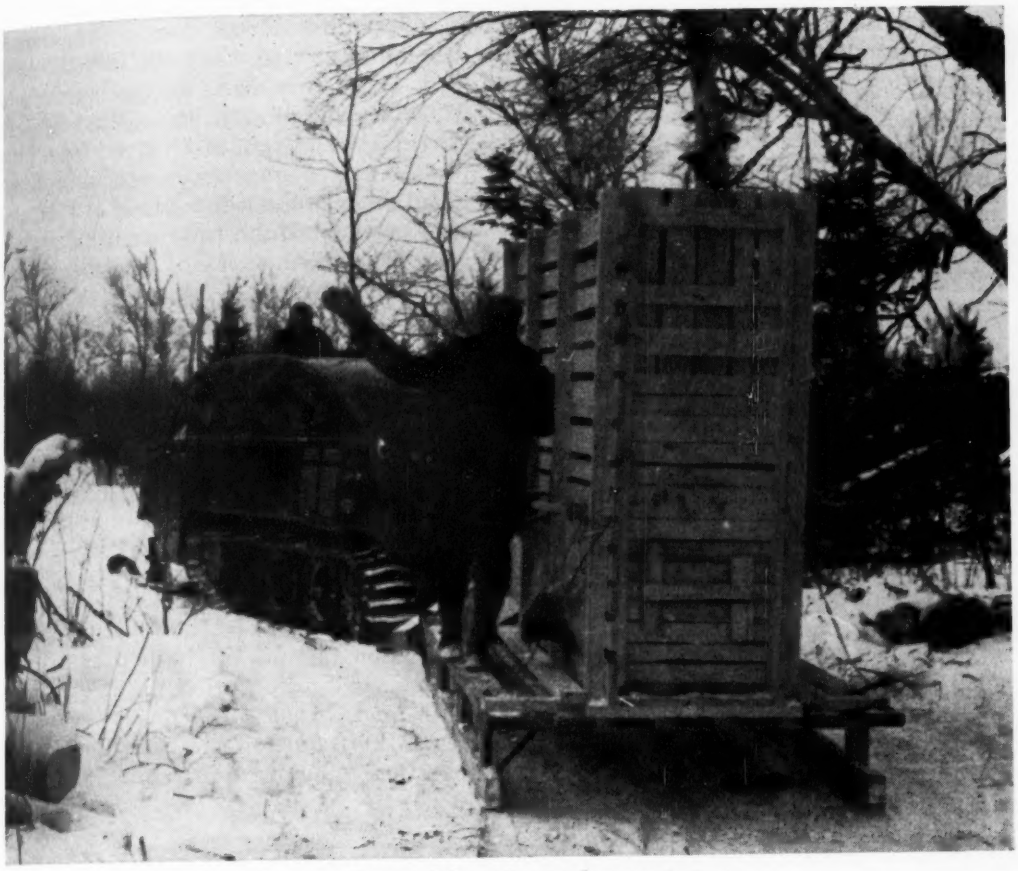

FIG. 5. Snowmobile with crated moose in tow.

to line up the second crate with the loading chute. For a month prior to this, the moose had to pass through a crate to enter the feeding corral. This familiarity with a crate may also have been a factor in the ease with which they were loaded.

Since the moose showed very little tendency to be nervous at this stage of the operation, they were not forced to lie down in the crate, to prevent them kicking, as they had been in the first trap-to-corral move. Only one animal kicked its crate during the trip to Labrador, this while it was being hoisted from the truck into the hold of the ship.

When released in Labrador the moose had been in the crates approximately 48 hours. They showed no ill effects or any evidence of stiffness.

Loading aboard ship.—A 500-ton motor vessel was chartered for the trip to St. Lewis River. She was ideally suited for the job, as she was a shallow-draft vessel and had stowage space in her hold for 25 crates.

At the loading port of Hampden, Newfoundland, the crates were hoisted by the ship's boom and lowered into the hold. The crates were stowed end to end in two banks of six crates each.

Unloading at St. Lewis River.—Logs were taken aboard at Hampden and during the voyage were made into a raft 12 feet long and 8 feet wide. After the ship was anchored in St. Lewis River, a rope was secured from the ship to the shore. The crated moose were loaded on the raft, one at a time, by the ship's boom. Then two men pulled the raft hand over hand to the beach.

When the raft grounded, the crate door was pulled up, releasing the moose.

Nova Scotia and New Brunswick to Newfoundland

Moose were introduced into Newfoundland on two different occasions. The first introduction of two animals, a bull and a cow, was made in 1878, and the second introduction of four animals, two bulls and two cows, was made in 1904 (Pimlott, *op. cit.*) (Fig. 1).

No details are available on how the Nova Scotia animals were obtained or transported to Newfoundland. The moose from New Brunswick were captured in a winter trapping operation in the Miramichi River area and were shipped by rail and water to Newfoundland. Eight animals were trapped in this operation. One bull broke a leg during the operation and was shot; three others, two cows and one bull, died at North Sydney, Nova Scotia, when they were held in a small enclosure during a shipping tie-up.

The present population of moose in Newfoundland is estimated at 30,000 to 40,000 and the annual kill now exceeds 4,500.

Quebec

Moose were introduced on Anticosti Island, Quebec, in the period between 1895 and 1905. We have not been able to ascertain the exact numbers introduced, where and how they were captured, or how they were transported to the island.

Newsom (*op. cit.*) stated that 20 moose were released in the Jupiter River area, but he gave no date; C. R. Townsend (1934) stated that 12 were introduced in 1897; and F. Faure, of the Consolidated Paper Corporation, advised the senior author that he has records which indicate that six were introduced in 1898 (personal communication).

Although the moose have persisted, they are not flourishing and have established a breeding population in only a small section of Anticosti Island (Pimlott, 1954).

New York

Hickie (*op. cit.*) gives information on an attempt that was made, early in this century, to re-establish moose in the Adirondack Mountains of New York. In 1901 the New York Legislature made an appropriation of $5,000 for the project. Fifteen moose were purchased, at prices that ranged from $100 to $150 apiece, and were released in designated areas in the Adirondacks in 1902 and 1903. Several of the cows were killed soon after they were released, and the project failed. According to Merrill (1916), the moose were mainly from Canada.

Western Canada to New Zealand

Moose were introduced into New Zealand from western Canada (Saskatchewan, and possibly Manitoba) in 1900, and again in 1910. The first introduction of four calves, two bulls and two cows, was made into Hokitika Valley, and was unsuccessful. The second introduction of ten young animals, presumably yearlings, was made into Dusky Sound (Donne, *op. cit.*). Although a moose population became established as a result of the second introduction, the animals have not extended their range much beyond the original introduction site, and it is thought that they may be dying out (Wodzicki, 1950).

Michigan

The largest moose-trapping operation yet undertaken was conducted on Isle Royale over three consecutive winters between 1934 and 1937 (Table 1). Seventy-one of the 77 moose transported from the island were immediately released in three areas of the Upper Peninsula of Michigan (Hickie, *op. cit.*). A few of the remaining six moose, held for a time at Cusino Wildlife Experimental Station, Upper Peninsula, were also later released (Bartlett, personal communication). The initial objective of the program was to determine the feasibility of controlling the Isle Royale moose herd by live trapping and removing animals from the island. A secondary objective was the re-establishing of a moose population on the Upper Peninsula of Michigan (Hickie, *ibid.*). It seems that, after the first winter's program, the main objective became one of obtaining animals for the re-establishment program, for Hickie's account contains no

further mention of the feasibility of live trapping and transplanting as a means of herd control.

I. H. Bartlett, of the Michigan Department of Conservation, has provided us with further background information on the success of the transplant and on the status of moose in the Upper Peninsula (personal communication): "There have probably always been a few moose in the Upper Peninsula. Every year our conservation officers and game management men report tracks, droppings, browsing, and occasionally sight records of moose, especially, and almost exclusively, in the eastern part." He went on to say that moose probably filter in from Ontario and that this ingress may be important in maintaining a Michigan moose population. Referring to the moose from Isle Royale, Mr. Bartlett stated that game-management men believe that the transplants resulted in only a temporary increase in the moose population of the Upper Peninsula. Within 10 or 15 years the population was again at such a low level that reports of only a few animals were obtained each year.

Wyoming

Intrastate moose transplants were attempted in Wyoming on three different occasions—in 1934, 1948, and 1950 (Grasse, *op. cit.*). In all, 39 moose were captured, of which 16 were successfully transplanted (Table 1). The 1934 transplant was wholly unsuccessful, for all 17 animals died on their way from Jackson Hole to Cheyenne. The moose for the 1948 and 1950 transplants were captured near Moran and released in the Big Horn National Forest. Sixteen animals were successfully transplanted in these two operations, eight in each year.

Alberta to Germany

In 1935 Dr. Lutz Heck was sent to Canada to obtain wild animals for the Berlin Zoo, and for release on game reservations in Germany (Heck, 1937). Seven moose, obtained from Alberta farmers, who had raised them as pets, were brought to a collecting point at Edmonton. Heck's account indicates that they were young animals and that at least two were bulls. The first moose was received at Edmonton on October 20, 1935. In February they were shipped by rail from Edmonton to New York, and by the liner *Bremen* from New York to Bremerhaven. They arrived at the Berlin Zoo on February 20, 1936, and, after a quarantine period, were taken to a game reservation.

At Edmonton the moose were first held together in a small enclosure, but it was later found necessary to place them in small separate enclosures. Twice a day they were given the freedom of a runway that joined the enclosures. No dimensions are given for the enclosures or the runway.

At the collecting point, the moose were conditioned to the sounds of nearby railroad trains and to a supplementary diet of oat sheaves, beets, carrots, potatoes, bread, rolled oats, and wheat bran. Natural browse was also provided, both during the captivity period at Edmonton and during the trip to Germany.

The moose were transported from Alberta to Germany in crates. Prior to shipping they were fed in the crates, and were so well conditioned to them that they learned to enter on command. They were confined to the crates for approximately two weeks, and all arrived in good condition.

Alberta to Nova Scotia

Although moose are indigenous to Nova Scotia, they were exterminated on Cape Breton Island early in the present century. The re-introduction of moose to Cape Breton National Park was made by the National Parks Branch of the Department of Northern Affairs and National Resources, in 1947 and 1948. In the two operations, 22 moose were shipped from Elk Island National Park, Alberta; of these, 18 were successfully transplanted (Banfield, personal communication) (Table 1). At Elk Island Park the moose were captured in buffalo-trapping corrals. These corrals and the trapping operation were described for the senior author by Dr. Banfield (pers. comm.) as follows:

"In the Park there are three large 50-acre enclosures. There are gates at intervals

along the perimeter of the enclosures. These were left open and blocks of salt placed in the enclosures in front of the gates. When a moose had been lured into an enclosure, the gates were shut. The moose was then driven into another enclosure used as a holding pen by several horsemen.

"Eventually, when enough moose were captured they were driven through one of the opened gates of the central enclosure into a long laneway which led to the corral. The corral is composed of stout poles and planks. On top is a cat-walk on which wardens can walk and drive the animals with poles. The corral has a reject pen, a squeeze and loading ramp.

"The moose were ear-tagged in the squeeze and then loaded into covered stock trucks. From Elk Island National Park they were transported 40 miles to Edmonton. Here they were loaded on a cattle car. Two temporary gates divided the car into two compartments with a central corridor for food storage and access.

"A water trough was placed in each compartment along with fresh baled willow shoots. Fresh willows were cut at four places enroute.

"Twelve moose were loaded at Edmonton on August 7, 1947. Four died enroute from exhaustion. Five adults and three calves were unloaded at Little Bras d'Or, Nova Scotia, on August 15, after a trip of 2,500 miles. They were then transported by stock truck a distance of 60 miles to the Park where they were released early the next morning.

"The initial losses were caused in part by the extremely hot weather in transit and the lack of segregation of the sexes in the cattle car. In 1948, a second shipment of five young cows and five young bulls was made. This time there were no losses.

"Subsequent investigations have indicated that the moose are thriving and increasing in Cape Breton Park and the surrounding country."

TRANSPORTING A MOOSE BY AIR

In 1954, the Newfoundland Department of Mines and Resources made a gift of a yearling cow moose, which had been born in captivity during the trapping operations, to a Netherlands zoo, Direnpark, Wassenar.

The cow was crated at Cormack, Newfoundland, on July 29, and was transported 200 miles to Gander in a half-ton pick-up truck. During the first half of the trip, the moose was extremely nervous. After a two-hour stop midway in the journey she quieted down considerably, but became very nervous later during a violent thunderstorm which lasted for two hours. The trip from Cormack to Gander required 11 hours.

After a four-hour stopover at Gander, the moose was loaded aboard a DC-4 aircraft of the Royal Dutch Airlines, on an animal cargo flight. The crate was loaded aboard the aircraft by a cargo-loading fork lift.

The flight from Gander to Amsterdam was made in ten hours and fifty-five minutes at an altitude of 9,000 feet. The aircraft was not pressurized. The groom reported that the moose was very quiet during the trip and appeared to have no ill effects from changes in altitude. During turbulence she lay down in the crate. She fed constantly on white birch that had been supplied for the trip, but she drank very little water. The groom's report ended, "Arrived at Amsterdam in a good calm condition. In all a perfect passenger" (Royal Dutch Airlines, pers. comm.).

No other records of moose being transported by air have come to our attention.

MORTALITY

In the more recent operations, for which fairly detailed records are available, in Michigan, Wyoming, Alberta, and Newfoundland, 123 wild-trapped moose were successfully transplanted to new areas. Sixty-two others died, either during trapping operations or while being transported to release sites (Table 1).

Mortality during Trapping and Transporting

In the Newfoundland operation all losses occurred during the trapping and holding period. The Michigan results were similar, with only three animals dying during the

transplanting stage of the work. The two operations on Isle Royale (Michigan) give a striking comparison of losses under conditions where, in one case (Chippewa Harbour), moose were trapped at the corral, and where, in the other case (Siskiwit Bay), they had to be transported up to 3 miles from trap to corral. At Chippewa Harbour, 2 died and 22 were transplanted; at Siskiwit Bay, 25 died and 55 were transplanted (Hickie, *op. cit.*).

In the two Alberta–Nova Scotia operations four moose died during the trip to Nova Scotia and none during capturing. In the three Wyoming operations 17 died while they were being transplanted, and four shortly after they were captured. From the results of these operations, it appears that mortality is much higher when it is necessary to transport the moose from trap to corral soon after they have been captured. The Isle Royale work provides the most clear-cut example of this correlation.

With the exception of the 1950 Wyoming operation, the general practice has been to hold moose in captivity for a considerable period before transplanting them. We believe that this is a desirable practice, for the animals, once conditioned to captive conditions, are less nervous, are easier to handle, and, in all probability, are much less subject to shock-type disturbances.

Relationship of Individual Crating to Mortality

In the Newfoundland and Michigan operations all transporting was done with crates, and, as has been shown in previous discussion, losses were very low in the final phase of the operation, when the moose were well conditioned to captivity.

In Wyoming, transportation crates were used in the 1934 operation in which all 17 moose died; however, there were no transporting losses in either the 1948 or the 1950 operation when the moose were transported in trucks with canvas-covered stockracks (Grasse, *op. cit.*). Grasse believed that the crating was largely responsible for the death of the moose in transit.

In the first shipment to New Zealand the moose were not crated, and 10 of 14 died during a storm in the first few days of the voyage (Donne, *op. cit.*). The ten moose in the second shipment were individually crated. They all arrived in New Zealand in good condition, although they also had encountered considerable rough weather during the long voyage. Donne (*ibid.*) believed that the individual crating was the reason for the complete success of the second operation.

The success of the New Zealand, German, Newfoundland and Michigan operations, where crates were used to transport moose from the corral to the release site, led us to conclude that, in spite of the heavy losses in the 1934 Wyoming operation, no clear-cut case can be made against transporting moose in crates, once they have been conditioned to captive conditions.

Causes of Mortality

On Isle Royale the principal cause of death of the 15 animals that died during the second winter was a hock infection. The organism was identified but is not named in Hickie's (*op. cit.*) account.

In the last two Wyoming projects the only animals that died were four calves that had been roped by a horseman. Although they were not treated roughly, and seemed to do well at first, all died, one within a week and all four within a month of the time they were captured. It seems possible that some form of injury may have resulted from the roping.

In the Alberta–Nova Scotia transplant the four deaths were attributed to exhaustion brought about by the extremely hot weather and by failure to segregate the two sexes in the cattle car.

Of the ten animals that died during the Newfoundland trapping, two died within 24 hours and three others within 48 hours. Others died on the third, fifth, seventh, twenty-fifth, and twenty-ninth days after trapping. In three cases, injuries received from fighting the trap were considered to have been contributing factors to death of the animals. In another case a septic condition that resulted from a minor cut was

believed to have been the cause of death. In six other cases the causes of death were not determined. Five of these six animals died between the first and fifth days after they were trapped.

In all cases the animals that died displayed more nervousness in the trap than those that survived, and showed much more fear of humans. We theorize that a shock condition may have been a factor in many of the losses.

SUMMARY

Moose-trapping operations were conducted in Newfoundland from January to April 1953, and 12 animals were introduced into the St. Lewis River area of southern Labrador in June 1953. In addition to those released in Labrador, ten died, seven were set free, and three escaped. Pole-type corral traps were used. The captured moose were transported in individual crates to the holding corral by sled and snowmobile, from the corral to the loading port by truck, and thence to Labrador by motor vessel.

In addition to the Newfoundland–Labrador project, transplanting programs have been conducted in and between the following areas: Isle Royale, Michigan, to the Upper Peninsula of Michigan between 1934 and 1937; intrastate trapping and transplants in Wyoming in 1934, 1948, and 1950; Alberta to Germany in 1936; Alberta to Cape Breton Island, Nova Scotia, in 1947 and 1948; Saskatchewan, and possibly Manitoba, to New Zealand in 1900 and 1910; Nova Scotia and New Brunswick to Newfoundland in 1878 and 1904; intraprovincial transplants from the mainland of Quebec to Anticosti Island, about 1900; and from Canada to the Adirondack Mountains, in New York State, in 1902 and 1903.

In 1954, a yearling cow moose was successfully shipped by truck and air from Newfoundland to a zoo in Holland.

The mortality of moose during trapping and transplanting operations has been high; on the average, for every two animals transported, one has died. Some of the factors that may have affected mortality are discussed.

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INFLUENCE OF WEATHER UPON A RUFFED GROUSE POPULATION

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This paper reports the degree to which year-to-year weather variations are associated with changes in the ruffed grouse (*Bonasa umbellus*) population of the Cloquet Experimental Forest, Minnesota, during the period 1927–55. The grouse-census data were obtained by King (1937) and Marshall (1954, and personal communication). The statistical technique employed is one developed by Fisher (1924).

The literature on the subject of animal population dynamics is a large one, but nevertheless there have been few quantitative studies of the effect of environmental factors, and especially weather, upon population densities. The work reported here constituted an attempt to learn whether an actual weather record might correlate significantly with ruffed grouse population changes, and whether a percentage of variation due to weather could be assigned.

We would like to express gratitude to William H. Marshall of the University of Minnesota for providing unpublished data of the Cloquet grouse census; to Joseph J. Hickey of the University of Wisconsin for his continual interest, support, and suggestions; to James H. Torrie of the University of Wisconsin for his advice on statistical matters; to Robert A. McCabe of the University of Wisconsin, and Frederic H. Wagner and Robert S. Dorney of the Wisconsin Conservation Department, for their aid and suggestions; to Preston C. Hammer and the staff of the University of Wisconsin Numerical Analysis Laboratory for their computing assistance; to Reid A. Bryson of the University of Wisconsin, who suggested that the Fisher method might have application to the problem and who was instrumental in obtaining the weather data; to Leslie Smith, director of the National Weather Records Office, Asheville, N.C., who provided the carded weather data; and to Harlow W. Halvorson of the University of Wisconsin, whose program for computing multiple correlations with the IBM 650 Magnetic Drum Data-processing Machine was employed.

The problem was conceived by the senior author, and skill and experience with programming the IBM machines for computations using the orthogonal polynomials were provided by the co-author.

History of the Statistical Method

The number of reported instances in which Fisher's (*op. cit.*) method has been used to study relationships between weather and crop yields is sufficient to indicate a fairly wide interest in this type of analysis. Fisher initially employed the technique to study the effect of rainfall upon the yield of wheat at Rothamsted, England. It was subsequently broadened to measure relationships between yield and a number of meteorological variables. Tippett (1926) used the method to measure the combined effects of sunshine and rainfall on wheat yield at Rothamsted; others who have employed the method are Wishart and Mackenzie (1930); Hopkins (1935, 1936); Davis and Pallesen (1940); Pallesen and Laude (1941); Davis and Harrell (1942); Houseman and Davis (1942); Schumacher and Meyer (1937); and Yang (1951).

Houseman (1942), Anderson and Houseman (1942), and Yang (*op. cit.*) have presented descriptions of the statistical method. The papers by Houseman give lucid directions for the computation of regression coefficients and for graphical presentation of the curves. The paper co-authored by Houseman and Anderson presents tables of the orthogonal polynomials to N=104. Their paper and one by Van der Reyden (1943)

provide mathematical descriptions and some of the historical development of the Aitken-Tchebychev orthogonal polynomials.

METHODS AND MATERIALS

In operation, the Fisher method employs orthogonal polynomials to obtain coefficients which characterize the annual distributional patterns of selected weather factors. The distribution coefficients are employed as independent variables in a multiple regression with the yield figure—in this study, the grouse-census figures—as the dependent variable. Partial regression coefficients are then employed in computation of the effect of units of weather on population density.

The method of Fisher allows a representation of the average effect of a weather factor (e.g., temperature) at various times throughout the year. Ordinarily, such a problem might be attacked as a multiple regression of the spring grouse population on several independent variables, each independent variable being the measurement of the weather factor during some period of the year. However, if these periods are made short enough to be ecologically informative, they become so numerous as to render the problem statistically impractical. Fisher pointed out that the changing effect of a weather factor throughout the year may be represented, using this method; it is the objective of this study to evaluate such a relationship and to demonstrate it (Fig. 1).

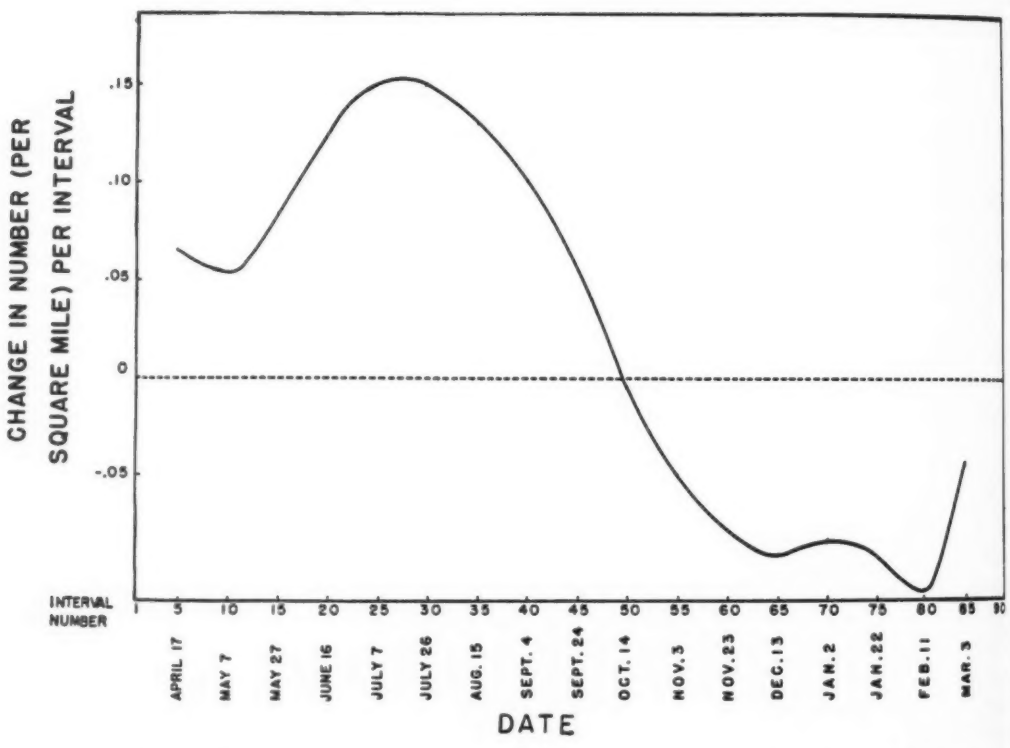

FIG. 1. This figure shows the effect on the Cloquet April grouse population of a degree above average of maximum temperature for each four-day interval throughout the preceding year. Above-average daytime temperatures during spring and summer are associated with an increase in the population; above-average daytime temperatures in winter result in a decrease in the April population. For example, a degree above average of maximum temperature during the interval dated May 7 will be associated with an increase of 0.05 over the average grouse population at the time of the subsequent April census; a degree above average during the July 7 interval, with an increase of 0.15; a degree above average during the Feb. 11 interval, with an 0.10 decrease, and so on.

For the purposes of this study, each of 25 years was divided into 91 four-day intervals (March 31 and February 29 were omitted), and four-day sums were computed for three weather factors—maximum daily temperature, minimum daily temperature, and precipitation.

The Cloquet Experimental Forest grouse censuses (Marshall, *op. cit.*) were taken in April (with one exception), and for this reason, the annual period taken for the study is the 12 months preceding each April. Thus, the 1927 grouse-census figure is correlated with the weather from April 1, 1926, through March 30, 1927. The year 1930 was omitted because of incomplete weather data, and the years 1937–39 were omitted because grouse-census data were lacking. For ease of calculation, the grouse census for 1946 was taken as one per square mile, although only one grouse was flushed along the entire census line of 16 miles.

In testing for correlations, each of the weather factors was employed as an independent variable, and these factors were tested for correlations with (1) the grouse-census figure, and (2) a number representing per cent increase or decrease in grouse population over the previous year. This latter number, hereafter called index of productivity, was computed by dividing the grouse census for any year by the previous year. For example, if the population had doubled over the previous year, the index would be 200. If it was half the previous year's population, the index would be 50. The year 1927 was assigned the value 100 because it was the first year in the series. The year 1947 was assigned the value 500 because the computed value, 2,500 was inordinately large; its use would have required a certain amount of reprogramming for computation with the IBM calculator, and it was felt that 500 adequately represented an increase of great magnitude. The index value for 1940 was computed from the 1936 census, the data for the intervening years being missing.

The weather data were recorded by the U.S. Weather Bureau at its Cloquet, Minnesota, station. Tables providing the results of the computations in detail have been compiled by Larsen (1957).

RESULTS

The only significant correlation to be found is that existing between maximum temperature and the grouse-census data. No correlations were apparent between minimum temperature or precipitation and the census figures. No apparent correlation exists between any of the three weather factors here employed and the index of productivity.

The significant partial regression coefficients shown in Table 1 were used to compute the average effect upon the grouse population of a degree of maximum temperature above average throughout the year, and this effect is shown in Fig. 1. The multiple coefficient of determination for the regression of maximum temperature is 0.53. This would indicate that half of the variability in the grouse population from year to year can be attributed to corresponding changes in the distributional pattern of maximum temperature.

TABLE 1.—REGRESSION COEFFICIENTS BETWEEN MAXIMUM TEMPERATURE AND GROUSE-CENSUS DATA[1]

Distribution Coefficients	Partial Regression Coefficients	Standard Error	Values of t
a_0	0.0350	0.0129	2.71[3]
a_1	–0.00209	0.000556	3.76[3]
a_2	–0.0000333	0.0000199	1.62
a_3	0.00000359	0.00000142	2.53[2]
a_4	–0.0000000500	0.0000000720	1.44
a_5	–0.0000000262	0.0000000118	2.22[2]

[1] Multiple coefficient of determination is 0.53.
[2] Significant at 0.05 level of significance.
[3] Significant at 0.01 level of significance.

Had the multiple coefficient of determination been sufficiently high, it would have been possible to employ an interesting adjunct of the Fisher technique to predict grouse populations. While predictions were not feasible with the coefficient of 0.53, it was postulated that if some inherent cyclic dynamic was at work within the grouse population, a regular or rhythmic pattern

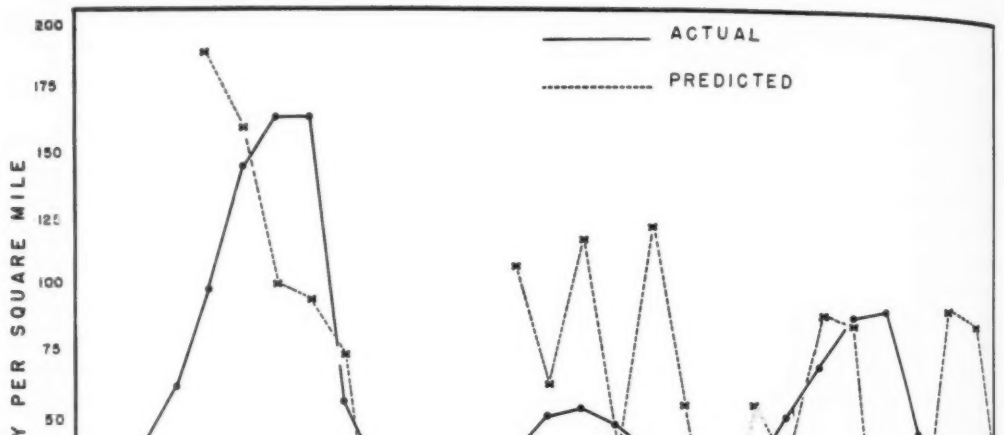

FIG. 2. Actual grouse population (census figure) and the predicted population obtained with the Fisher prediction technique.

might exist in year-to-year differences between census figures and prediction values. Fig. 2, however, reveals that no readily discernible regularity does exist in these deviations. The correlations between predicted and actual values were 0.50 for the portions of the census curve above the average and 0.34 for the portions of the census curve below the average; in other words, prediction was slightly better during the periods in which the census figure approached or declined from a peak.

DISCUSSION

It might be pointed out initially that application of the Fisher prediction technique is complicated by a fundamental difference existing between game crops and grain crops. This complication must be taken into account only with the prediction technique, not with the evaluation of general effects of weather upon yield, but it would seem to make subjective evaluation of data necessary, even when a high multiple coefficient of determination might make predictions possible. Grain crops will, under most circumstances, survive a period of adverse weather and live on to recoup losses in growth rate or yield if exceptionally favorable weather prevails thereafter. A grouse population, on the other hand, cannot increase above the level at which it survives a period of unfavorable weather, no matter how favorable subsequent weather might be. Yet, the Fisher method is so devised that the number obtained by use of the prediction technique can become not only negative at any time during the year but, if once negative, can become positive again and continue upward through ensuing periods of favorable weather. The result, when applied to grouse populations, might be a sizable predicted population for the year-end, when disasters during previous months had indicated no survival whatsoever. The method, however, does offer an

opportunity for inspection of the year's weather, and an evaluation of the importance of weather events, interval by interval; from this it might seem possible to evaluate subjectively the effect of weather upon a grouse population. It was not possible, however, to find any weather patterns that, upon subjective evaluation, seemed to cause definite and consistent trends. It is apparent that unexplained variability in the census results was so great that application of the prediction technique in this subjective fashion was also ineffective. The same situation existed in other reported studies in which the Fisher technique was used, in at least one of which the multiple coefficient of determination was 0.65. The technique cannot, thus, be expected to function when the coefficient is only 0.50.

The subject of the unexplained variation is, of course, a pertinent one, and the assumption must be made that this remainder of variation must be due to other density-independent factors, to density-dependent factors, or to variations in the census technique, but this does little more than assign generalized names to an unknown.

While the statistical analysis indicates quite clearly that the April grouse density on the Cloquet area reflects in part the pattern of maximum temperature during the previous 12 months, the proximate causes of mortality in the grouse population remain, of course, unidentified. The correlation between grouse density and maximum temperature patterns does not imply that the correlation is with maximum temperature alone, but rather that it is with those environmental conditions that maximum temperature patterns induce or reflect. It is, indeed, a correlation with any or all environmental factors associated with maximum temperature, or even with wholly unrelated ones if they, by chance, correspond in their variations with the variations of maximum temperature, however unlikely such an occurrence might be.

The hypothesis that weather plays an important role in the determination of gamebird densities is, of course, not a new one. Some investigators (Cahn, 1938; Twomey, 1936; McCabe and Hawkins, 1946) used climographs to explain differing intraspecific densities. Shelford and Yeatter (1955) used a paired-factor technique to study the effect of weather upon fecundity. Edminster (1947) made studies of the correlations between New York weather records and grouse populations through four major and three minor grouse declines in that state. He concluded that "every time severe February-March snow conditions and very low temperatures, followed by a very cold June, occurred in two successive years, a grouse decline followed." Crissey (in Bump, *et al.*, 1947:306) confirmed that low temperatures in March and June seemed to precede the onset of periods of grouse scarcity, but that there was an "unaccountable lag of a year between the two." He said also that no connection seemed to exist between weather and early-season mortality, and that mean temperature from July 16–August 31 was more important. "Losses at this time," he wrote, "have been constantly higher in those years in which June temperatures have been below average and, conversely, they have been lower when temperatures have been above average."

In a discussion of population fluctuations in northern-hemisphere game birds, Williams (1954) wrote that, at the time, "all attempts to find a climatic factor correlated with the population changes have failed," despite the fact that "it does seem that weather systems must play an important part." Williams further speculates that, if weather influences grouse-population densities, there should be some degree of synchrony between cycles over large areas. It is perhaps of interest to note here that some parallels seem to exist in the cycles at Cloquet, in Canada (from Williams, *ibid.*), and in the Wisconsin hunting-kill data (on file in the Wisconsin Conservation Department). Moran (1954) reports finding correlations between spring and winter weather with population changes in grouse on Scottish estates, but he was unable to confirm with statistical evidence the idea that synchrony existed between the three species studied.

From Fig. 1 we draw the conclusion that high maxima in April of a given year tended to result in high grouse populations at the time of the census of the following April. Some hints to an explanation for this can perhaps be drawn from the work of Frederic H. Wagner (MS now in preparation). This work was conducted with pheasants (*Phasianus colchicus*), but in general principle it could also apply to grouse populations. Wagner finds in degree-day studies that early hatching dates are correlated with spring periods characterized by high mean temperatures, and that both early hatching dates and warm springs are correlated with increases in fall pheasant populations. He points out that pheasant hens begin laying at about the same date each year, but they begin incubating earlier in those years characterized by warm springs, and, thus, the broods are hatched from eggs laid early in the season. These eggs are generally heavier than eggs laid later in the season, and clutches and broods produced from them show lower mortality rates than those produced from eggs laid later in the season. It seems likely that an early spring might also tend to produce healthier broods in grouse as well as in pheasants.

Wagner (*ibid.*) also points out that pheasants cannot renest successfully after a certain date, and late nesting, therefore, cuts short the time available in which renesting can be a successful venture. While grouse do not renest to any important extent (Edminster and Crissey, in Bump, *et al., op. cit.*: 364), renesting that might occur would have a reduced chance of success if the date of first nesting was late. There is also accelerated hen mortality in pheasants in the latter part of the summer and, according to Wagner, this is more severe in a late than in an early year.

Another point in regard to nesting success in pheasants is brought out by Kozicky and Hendrickson (1956), who state that adverse spring weather can delay the growth of oats and that this delay can reduce nesting success in Iowa. Similar weather effects involving different plants may be at work in grouse habitat.

From Fig. 1 we note that high maximum temperatures in April do not seem to be nearly as important to the maintenance of high populations as do high temperatures later in the summer. Darrow (in Bump, *et al., op. cit.*:572) has summarized existing evidence that summer mortality has at times caused marked declines in ruffed grouse population levels. As the hatching peak is reached (May 27–June 9 in northern Wisconsin, according to Hale and Wendt, 1951), it becomes more important for grouse survival that high daily maximum temperatures occur. This may be due in part to lowered resistance of chicks if they are exposed to excessive or unremitting cold. It may also reflect the need for warm days to bring about proper increases in insect activity or abundance. Criddle (1930) has pointed out that grasshopper abundance is necessary for sharp-tailed grouse chicks (*Pedioecetes phasianellus*) to survive. Insects are an important food for ruffed grouse chicks (*see* Bump and Jones, in Bump, *et al., op. cit.*: 212), but different insect species are probably involved.

As summer wears on, the effect of above-average daytime temperatures becomes progressively less important. With the approach of winter, high daily maxima become detrimental. This may be the result of snow crusting and increased predation associated with warm winter days. Crissey (in Bump, *et al., ibid.*:302) and Edminster (*op. cit.*: 188) claim that snow crusting is overplayed as a mortality factor and point out that no record exists, in the New York investigation, of grouse mortality occurring beneath a crust. Clarke (1936) also holds the view that crusting is not important, but points out that seven correspondents bore "witness that they had seen the dead bodies of grouse so killed."

The hypothesis that crusting brought on by warm days or by rain turning to sleet prevents grouse from gaining access to, or egress from, the protective blanket of snow for roosting is confirmed by Robert S. Dorney (personal communication). From his study of grouse in northern Wisconsin, Dorney concludes that years with soft, un-

crusted snow are characterized by lower winter mortality rates than are those years in which hard snow conditions prevail. His field studies indicate that the insulation value of soft snow for roosting appears to be necessary for good overwinter survival.

Grange (1949:169) asserts that the blanket of deep snow in the north is used as roosting cover and that, if crusting makes this snow unavailable, the grouse suffer increased exposure to predators. With hard snow, predators hunt with great intensity because the crust serves as an effective protection to grouse buffer species, the rodents.

Edminster (*op. cit.*:189) points out that winter sleet can make budding difficult or impossible. He adds, however, that grouse can go several days without food, and the ice sheath would have to persist for a long time to be a serious hazard. The role of disease in grouse mortality is still a much-debated question, but any events that prevent grouse from obtaining sufficient food or adequate cover would presumably lower their resistance to infection. The same factors will also reduce reserves of energy available for surmounting the physiological stress of crowding or reproduction. Christian and Davis (1956) and others have shown that crowding causes apparent stress in small mammals. It is conceivable that a grouse population already suffering stress, from whatever cause, would crash under the additional weight of adverse weather conditions. This, indeed, is Frank's conclusion regarding the population-crash mechanism in *Microtus agrestis* (Frank, 1957).

It has already been noted (*see* Results) that, in using the Fisher prediction technique, the predictions were somewhat more accurate for those periods in which the census figure approached or declined from a peak. This tendency might indicate that weather effects are more critical when population densities are high. At such times, adverse weather may be a secondary stress that dense populations cannot withstand and, hence, may initiate the population decline.

In conclusion, the present study has singled out a weather factor that seems to be an important determinant of grouse densities at Cloquet. The proximate causes of the deaths of individual grouse will remain speculative until field, and perhaps laboratory, research has revealed them more clearly. Perhaps the study reported here will fulfill its most important function by having delineated the periods of the year in which maximum temperature is most operative as a factor limiting grouse survival.

It might be of interest here to note that weather records for many of the nation's major weather stations are available on punched IBM cards from the National Weather Records Office at Asheville, N.C., and individuals and organizations may obtain further information on them directly from Leslie Smith of that office.

SUMMARY

A statistical technique developed by Fisher (1924) has been employed to demonstrate that about 50 per cent of the variability of the ruffed grouse population of the Cloquet Experimental Forest in Minnesota during the years 1927–55 is associated with corresponding annual changes in the distributional pattern of maximum temperature.

The curve depicting the effect of a degree above average of maximum temperature throughout the year shows that warm days in spring and summer tend to be associated with a high grouse population the following April, and that warm days during winter tend to be associated with a low grouse population the following April.

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RACIAL DETERMINATION OF ORIGIN OF MOURNING DOVES IN HUNTERS' BAGS

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Proper management of migratory game birds requires the ability to relate birds that are harvested to their area of production. This ability must be acquired to determine whether the birds harvested at different times or in different places have different breeding areas on which population information is available. It therefore permits formulation, with more confidence, of regional hunting regulations based on the condition of the population. One method of obtaining information that contributes to this knowledge with respect to the mourning dove, *Zenaidura macroura,* is the identification of racial components of the contents of hunters' bags, since each race is restricted to a definite breeding area. The purpose of this paper is to describe the application of this method in analyzing the contents of hunters' bags in two important dove-hunting areas, Texas and Georgia.

Methods and Materials

By examination of the wings of mourning doves collected in the United States and Canada, it is possible to differentiate three groups based on color: a pale, a dark, and an intermediate group. These have been found by Aldrich and Duvall (in press) to represent the two races of doves that breed in continental North America, an eastern and a western race, and an intermediate population, produced presumably by genetic mixture, within a zone where the breeding ranges of the two races blend. The breeding ranges of these two races and their intermediate population, minus that portion of the range of *marginella* extending southward into Mexico, are shown in Fig. 1. The West Indian race, Z. *m. macroura,* is not discussed in this paper because it seldom occurs north of the Florida Keys (Aldrich, 1952).

The western race of mourning dove, Z. *m. marginella,* is distinguishable from the eastern race, Z. *m. carolinensis,* in all plumages by the shade of coloration. There is no difference in the pattern of the markings. All feathers are of a lighter tone, giving an over-all impression of paleness in the western as compared with darkness in the eastern birds. This difference, although distinct in typical specimens, is relative, and can be accurately determined only by comparison with specimens representing the breeding ranges of the two races. The intergrading populations exhibit shades of coloration intermediate between those of typical eastern and western races.

A complicating factor in delineating the zone of intergradation or morphological intermediacy between the two races is the occurrence, in this zone, of numerous individuals that look like typical examples of both *marginella* and *carolinensis.* It has been pointed out by Aldrich and Duvall (*op. cit.*) that the distribution of these birds appears to be correlated with the highly interdigitated boundary separating the western prairies from the eastern deciduous forest zones. Whatever the cause, the result is a mixture, within this intermediate zone during the breeding season, of examples that look like typical *marginella,* and others like typical *carolinensis,* but with the majority appearing to be a blend of the two. As a result of this situation, in attempting to assign a region of origin to doves collected in regions away from their breeding grounds, it is necessary to consider birds with the characters of *carolinensis* as originating either from the eastern or the intermediate area, those with the characters of *marginella* as originating either from the western or the intermediate area, and those with the characters of intergrades as all originating from the intermediate area (*see* Fig. 1).

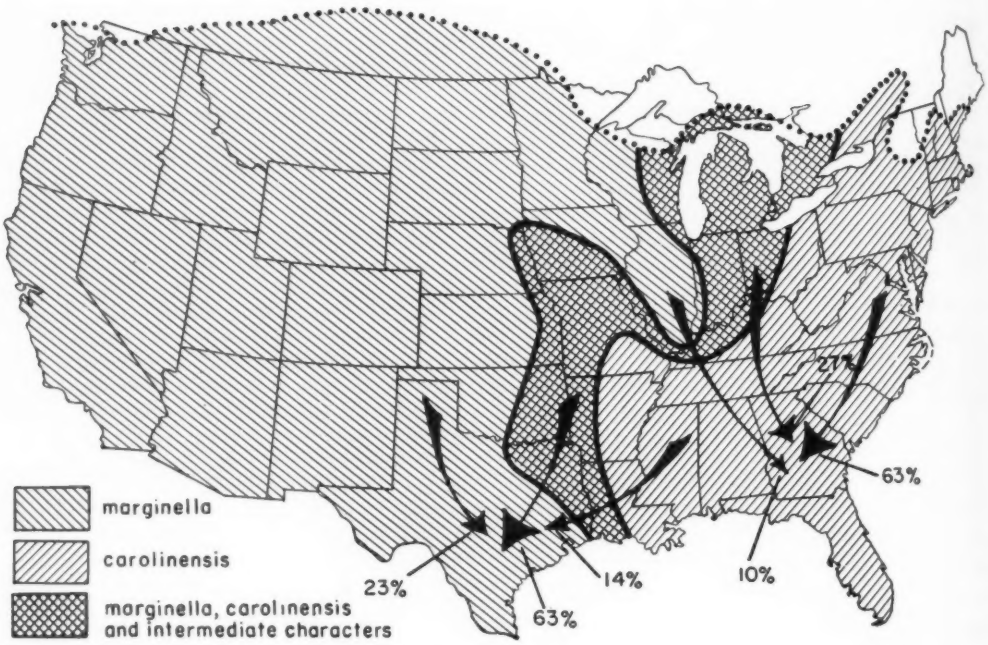

FIG. 1. Determination of racial characters of the origin of mourning doves in hunters' bags.

The characters that distinguish the eastern and western races of the mourning dove and their intermediate population are as easily discernible from a single wing as from the complete specimen. This facilitates the collection of samples of harvested doves because hunters are almost always willing to have wings removed from their birds. Our attempts to identify the same specimens under field conditions and in the laboratory convince us that the latter is far more reliable. All data presented in this paper are based upon wings examined in the U.S. National Museum laboratory of the U.S. Fish and Wildlife Service under ideal conditions of uniform light and adequate comparative material. The wing samples from Georgia were collected from hunters by game wardens during the 1952 season from 37 different counties. The Texas sample was obtained in 1952 in a similar manner from 38 counties. It is assumed, but not known, that these samples are representative of the populations from which they were taken. These data are presented in Tables 1 and 2, respectively.

There are two very important concentration areas of migrant mourning doves from breeding areas in the eastern United States: (1) west of the Gulf of Mexico in southern Texas, and (2) east of the Gulf in southern Georgia and northern Florida. Recoveries of banded birds indicate that doves funnel into the Texas area from breeding grounds in the eastern half of the United States as far east as the Appalachian Mountains and into the Georgia–Florida corner of the United States from eastern breeding areas as far west as the Mississippi River (Taber, 1930; Low, 1935; Austin, 1951; and Peters, 1956). These conditions make these two concentration areas very important from the standpoint of dove harvest and management. For this reason, samples of dove wings were obtained from hunters' bags in these two areas in the hunting seasons of 1952 in Texas and Georgia. These were identified as to race by the above-described method and aged by a modified method first suggested by Moore and Pearson (1941: 21,35) and developed by numerous workers in the Cooperative Mourning Dove Study of

the southeastern United States (Southeastern Association of Game and Fish Commissioners, in press).

For assistance in obtaining the samples of wings, we are indebted to numerous agents of the Texas Game and Fish Commission, the Georgia Game and Fish Commission, and the U.S. Fish and Wildlife Service.

RESULTS

The Georgia sample was divided into doves shot early (September) and late (January) in the season, and those bagged north and south of the "Fall Line," which divides the Piedmont from the Coastal Plain. It is evident that no difference existed in the racial composition between northern and southern Georgia during the two time periods. Therefore, this geographic division has no significance with respect to racial composition of the kill. However, a marked change occurred in the racial composition of the Georgia dove kill during the season. Eighty per cent of the kill during the early period (September 15–29) consisted of the eastern race, *carolinensis*. In contrast, during the late period (January 15–29) only 19 per cent of the bag was composed of *carolinensis*. The midwestern (intermediate) and western (*marginella*) forms increased from 18 and 2 to 51 and 30 per cent, respectively. These changes were very highly significant ($P<.0005$)—less than five chances in ten thousand. It can be concluded that production within the breeding areas of *marginella* and the intermediate group influenced the late-season shooting, while the production within the range of *carolinensis* influenced the kill during the early part of the 1952 Georgia season.

It should be pointed out that the racial composition in the total sample indicated in Table 1 and Fig. 1 may not reflect the true racial composition in the entire season-long hunter kill. This is true because the racial composition changed greatly during the season, and it is not known if the sample collected during the two periods was directly proportional to the kill during the periods. This emphasizes the importance of thoroughly understanding both quantitatively and qualitatively to what a sample relates if it is to be meaningful.

The Texas wing-sample data are divided into three parts: (1) birds shot in the Rio Grande Valley during the three-day joint white-winged dove–mourning dove season (September 12, 14, and 16); (2) those col-

TABLE 1.—OCCURRENCE OF MOURNING DOVE RACES IN GEORGIA IN THE FALL AND WINTER SEASONS OF 1951 AND 1952 FROM ANALYSES OF HUNTERS' BAGS

	Northern[1]			Southern[1]			Total		
Season	Race	Number	Per Cent[2]	Race	Number	Per Cent	Race	Number	Per Cent
Early (Sept. 15–29)	carolinensis	345	80.8	C	243	78.9	C	588	80.0
	intermediate	74	17.3	I	59	19.2	I	133	18.1
	marginella	8	1.9	M	6	1.9	M	14	1.9
	subtotals	427	100.0		308	100.0		735	100.0
Late (Jan. 15–29)	carolinensis	8	19.1	C	47	19.2	C	55	19.2
	intermediate	24	57.1	I	123	50.2	I	147	51.2
	marginella	10	23.8	M	75	30.6	M	85	29.6
	subtotals	42	100.0		245	100.0		287	100.0
Totals	carolinensis	353	75.3	C	290	52.4	C	643	62.9
	intermediate	98	20.9	I	182	32.9	I	280	27.4
	marginella	18	3.8	M	81	14.7	M	99	9.7
	grand totals	469	100.0		553	100.0		1,022	100.0

[1] Northern refers to that part of the state north of the edge of the Piedmont or "Fall Line"; southern refers to that part of the state south of the edge of the Piedmont or "Fall Line."

[2] Percentages here and in Table 2 are carried one digit past the decimal point for comparative purposes only.

TABLE 2.—OCCURRENCE OF MOURNING DOVE RACES IN TEXAS DURING FALL OF 1952 FROM ANALYSES OF HUNTERS' BAGS

Determination		Sept. 18–30 Northern Zone[1]		Oct. 1–19 Southern Zone[1]		Sept. 12, 14, and 16 Rio Grande Valley		Totals	
Age	Race	Number	Per Cent	Number	Per Cent	Number	Per Cent	Number	Per Cent
Young	carolinensis	100	21.2	48	11.5	16	17.6	164	16.7
	intermediate	304	64.4	264	63.1	68	74.7	636	64.8
	marginella	68	14.4	106	25.4	7	7.7	181	18.5
	subtotals	472	100.0	418	100.0	91	100.0	981	100.0
	per cent young[2]		61.6		61.4		48.7		60.0
Adults[3]	carolinensis	28	9.5	15	5.7	27	28.1	70	10.7
	intermediate	182	61.9	156	59.3	58	60.4	396	60.7
	marginella	84	28.6	92	35.0	11	11.5	187	28.6
	subtotals	294	100.0	263	100.0	96	100.0	653	100.0
	per cent adult[2]		38.4		38.6		51.3		40.0
Totals	carolinensis	128	16.7	63	9.3	43	23.0	234	14.3
	intermediate	486	63.5	420	61.6	126	67.4	1,032	63.2
	marginella	152	19.8	198	29.1	18	9.6	368	22.5
	grand totals	766	100.0	681	100.0	187	100.0	1,634	100.0

[1] The boundary between the northern and southern zones is the southern boundaries of Val Verde, Kinney, Uvalde, Medina, Bexar, Comal, Hays, Travis, Williamson, Milam, Robertson, Leon, Houston, Cherokee, Nacogdoches, and Shelby counties.

[2] Based on the total number in each vertical column.

[3] Only those specimens were used that still had at least one unmolted old worn primary showing definitely that they were adults rather than young of the year that had completed the molt into adult pulmage. Specimens in which the molt had been completed and thus were indeterminable as to birds of the year or true adults numbered 84, and were excluded from this table.

lected throughout the northern zone (September 18–30); and (3) doves shot in the southern zone (October 1–19). The boundary between the northern and southern zone is the southern boundaries of Val Verde, Kinney, Uvalde, Medina, Bexar, Comal, Hays, Travis, Williamson, Milam, Robertson, Leon, Houston, Cherokee, Nacogdoches, and Shelby counties. Only a portion of the northern zone was within the breeding range of the intermediate population. The other samples from the southern zone and the special white-wing season were all from within the breeding range of *marginella*.

The wings were aged as to having come from an immature, adult, or an unknown-age bird. Those birds that had completed their wing molt and, therefore, could have been either adult or immature were placed in the unknown-age category, which comprised only 4.9 per cent of the total sample. Only wings that could be definitely determined as having come from a bird of the year or adult by the presence of at least one unmolted primary were included in Table 2.

In contrast to the early-season Georgia sample, the early southern Texas samples were comprised mostly of obvious migrants. Also, many of these birds were produced in areas from the north and east, since *carolinensis* and intermediate forms made up much of the bag. At no time or place could the bag in southern Texas have been made up largely of birds of local origin, since examples of the breeding race of that region were in the minority. It is also noteworthy that in both the northern and southern zones there were highly significant differences ($P<.005$ and $P<.001$, respectively) in the racial composition of the two age groups. In both zones there were relatively more *carolinensis* and fewer *marginella* among birds of the year than there were among adults.

For example, in the northern zone the ratio of adults to young in *carolinensis* was 1:3.6, while for *marginella* the age ratio was 1:0.8. There are three possible explanations for this: (1) that the productivity of the eastern form had been much greater than that of the western form; (2) that the bag-check samples were biased in some way; or (3), most likely, that immature doves tend to migrate before the adults. This would result in the movement of immature *carolinensis* into the area while the locally produced young *marginella* were moving south into Mexico, leaving the numerically fewer adults behind.

The racial composition in the bags in Georgia and Texas suggests that doves produced in the eastern half of the United States, west of the Appalachian Mountains, contributed to both the Georgia and Texas kill. This conclusion is supported by banding evidence presented by Taber (*op. cit.*), McClure (1943), and Peters (*op. cit.*). It is also evident from this study and banding data (Taber, *op. cit.*) that birds from that production area arrive in Texas earlier than they reach Georgia.

SUMMARY

A method is described for determining the general area of production of mourning doves that are shot during the hunting season. This procedure is based on the identification of racial characteristics that can be ascertained from samples of wings. The application and utility of this method were demonstrated with data gathered from doves shot in two important dove-hunting areas, Georgia and Texas. The Georgia data indicated that the early-season kill consisted largely of the race *carolinensis*, while later in the season *marginella* and the intermediate form made up most of the bag. The wing samples from Texas indicated that birds produced outside of southern Texas made up the largest part of the bag in southern Texas during the entire season. Doves produced west of the Appalachians contributed to both the Georgia and Texas kill.

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EFFECTS OF DIELDRIN ON FISHES AND INVERTEBRATES OF A SALT MARSH[1]

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In May of 1955 about 2,000 acres of salt marsh in St. Lucie County, Florida, were treated with dieldrin[3] with the object of eliminating sandfly (*Culicoides*) larvae. The pelletized toxicant (active ingredient, 10 per cent; inert ingredients, 90 per cent, comprising 2/3 attapulgus clay granules 16/30 mesh and 1/3 bentonite 13/40 mesh) was applied by airplane at the rate of one pound of active ingredient per acre. Most of the acreage had been ditched for mosquito control years ago, and a large portion of ditched marsh on Hutchinson Island had later been diked off for de-watering as a sandfly-control measure. During the last war, however, the dike was breached at several points, and Indian River tides have circulated freely through the marsh for over ten years. Here, as elsewhere in the area treated with dieldrin, vegetation was of the scrub mangrove association (cf. Davis, 1940) and *Batis–Salicornia* marsh type. Of 2,000 acres treated, 1,600 were ditched, with 354,000 feet (67 miles) of ditches. In resorting to dieldrin, the county government concerned exercised its own prerogative; this treatment was not undertaken at the recommendation of the Entomological Research Center of the Florida State Board of Health. Since the center was initiating a study of fish predation on mosquitoes, however, it was decided to make of the anticipated fish kill an opportunity to learn something about fish populations of antimosquito ditches and their reactions to dieldrin. Thus, except for time and place, the activities of treatment and observation were totally unrelated and were conducted by separate organizations.

It cannot be overstressed that casual observations of fish activity in such terrain are highly misleading. Only under unusually favorable conditions is it possible to gauge numbers and kinds of fishes present without collecting. Yet quantitative sampling is largely a delusion owing to complex tide-influenced water movements within the ditch systems and to little-understood fish movements; and it is hampered by turbidity, marly muck bottoms, and ill-defined, pneumatophore- and root-bordered ditch margins. The joint effect of these factors is great variability in catch per unit of effort and time. With methods presently available, the composition of salt-marsh fish populations can only be defined gradually, as seasonal and secular collections accumulate. Hopes of a workable sampling procedure seem to lie in the development of a set of traps collectively effective for fishes of each category of habit within the marsh, and in the use of such traps on a trap-hour basis with due regard to tidal cycles. Seining is ineffectual because rapid progress is impeded by the soft bottom, although bag seines have their uses. Spot poisoning with rotenone is difficult to control because of unpredictable water movements and poor recovery of dead animals among vegetation and in mud. Finally, fishes poisoned in such regions either for collecting purposes or through inadvertency, if not recovered at once, are set upon first by crabs, then by snails, and within a surprisingly short time no apparent trace of them remains. Thus, observations on effects of toxic substances on salt-marsh fishes are usually invalid un-

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[3] 1, 2, 3, 4, 10, 10-hexachloro-6, 7-epoxy-1, 4, 4a, 5, 6, 7, 8-dimethanonanaphthalene.

less the recovery of moribund and dead fishes is begun at the outset of poisoning and continued energetically by experienced personnel as long as the poison is acting.

In order to direct this paper to the regional audience most concerned, some vernacular names other than those recommended by the American Fisheries Society have been used, but in each case the official vernacular synonym is indicated once in the present paper.

PROCEDURE

The main application of dieldrin pellets was made between 5 and 10 A.M. on May 10, although a narrow swath was strewn with pellets between 5 and 6 P.M. on the previous day. The observation post for evaluating the effects of this treatment was a ditch 5,600 feet long running due east and west across the widest expanse of marsh treated, which extended from the western marginal ditch behind the dike next to Indian River to the eastern marginal ditch behind the ocean beach barrier on Hutchinson Island. The westernmost 1,100 feet were marked off for fish pickup as the bottom was hard and sandy and the banks well defined. Following treatment, the entire 5,600-foot ditch was patrolled at 2-week intervals to assess duration of toxicity and rate of recovery. The combined choices of ditch and treatment date proved exceptionally favorable for observations. The whole ditch remained clear, and objects anywhere in it—except within algal patches—were easily discernible for ten weeks when we were censusing its fish. In retrospect, it seems probable that the lack of turbidity owed as much to the scarcity of bottom-disturbing fishes as to weather conditions.

Besides the long ditch, a 200-foot segment of the eastern marginal ditch behind the beach barrier was used for fish pickup during the abortive treatment of a narrow swath, parallel with and including that marginal ditch. This premature application of dieldrin, made late in the day of May 4, was halted by unusually high water, but proved a valuable dress rehearsal for the observers, who were enabled to select an optimal vantage point before May 10. The results at the marginal ditch on May 4 will be described first, and further reference will be made to the May 10 results and observations along the 5,600-foot ditch. Both ditches were about 15 feet wide and 1 to 2 feet deep according to tide level.

IMMEDIATE EFFECTS OF DIELDRIN PELLETS

On May 4, fishes within the 200-foot segment of ditch reacted to the toxic stimulus within a few minutes after pellets fell into the ditch, and barrier screens were then erected across each end of the segment. Recovery of dying fishes was begun at once, continued as long as light permitted, resumed early the next day, and continued until further efforts (*see* below) would have been unrewarding. From the general absence of small specimens and the difficulty of locating fishes on the bottom in contrast to the known thorough recovery, including very small fishes, in the long ditch during the main treatment, we estimated that 15–25 per cent (by weight) of the fishes were not recovered. Most specimens were taken in D-nets as the fish thrashed about the surface, others were picked up where they had nosed among mangrove pneumatophores bordering the ditch or flipped far back from the ditch margin; the rest were retrieved from bottom mud wherever their white bellies could be seen. Table 1 enumerates the fish recovered.

The definitive treatment was completed at 10 A.M. on May 10, just as the tide turned and began to ebb. The last passages of the airplane north and south were over the westernmost portion of the marsh, so that the 1,100 feet of ditch chosen for fish pickup were in that part treated last. Fish were picked up continuously by the two authors from west to east and east to west in the 1,100-foot ditch segment for the next seven hours (14 man-hours). Only the smallest specimens were lost, as the bottom was clearly visible, but unremitting effort was needed to keep ahead of the crabs, which set on the dying fishes, although toward the end of the day the crabs themselves were succumbing to the poison. The depre-

TABLE 1.—FISH IN 200 FEET OF THE EASTERN MARGINAL DITCH. KILLED BY THE MAY 4 APPLICATION OF DIELDRIN PELLETS

Species	Number	Pounds
Ten pounder or bigeye herring (*Elops saurus*)	1	—
Sea catfish (*Galeichthys felis*)	4	—
Sailfin molly (*Mollienesia latipinna*)	2	—
Striped mullet (*Mugil cephalus*)	86	17¾
Snook (*Centropomus undecimalis*)	7	1⅝
Irish pompano (*Diapterus olisthostomus*)	237	15⅛
Channel bass or red drum (*Sciaenops ocellata*)	1	—
Spot (*Leiostomus xanthurus*)	12	—
Sheepshead (*Archosargus probatocephalus*)	7	1⅞
Totals (9 species)	357	37

dations of snails were slower but unrelenting. Fish pickup was resumed the next morning and continued for three hours (10:30 A.M.–1:30 P.M.) or six man-hours, east to west against the flood tide, and was ended at the turn of tide, when returns had so diminished as to discourage further efforts. Dead crabs of several kinds littered the bottom. The only surviving crustaceans seen were a scattering of fiddler crabs (*Uca* spp.), from the multitudes thronging the marsh on the preceding day, which had evidently been spared by an hiatus here and there in the dispersion of pellets. Many fishes picked up this morning were mutilated by the activities of snails (unidentified), with which they were covered, but all of the aquatic crabs (portunids, xanthids, etc.) were dead. The larger fishes, sorted out as collected, were weighed by M. W. Provost and J. S. Haeger, thus freeing the authors for continuous collecting, totaling 20 man-hours. The fishes killed on May 10–11 in the 1,100-foot segment are enumerated in Table 2.

BIWEEKLY POSTTREATMENT FISH CENSUS

At biweekly intervals after the catastrophic fish kill of May 10–11, a canoe was paddled the length of the 5,600-foot ditch, and each time the same observer, standing in the bow, counted or estimated the numbers of each species encountered in one east to west transit across the marsh. The counts and estimates were then summated for each species (Table 3). Despite obvious shortcomings, this procedure was the best available, and under the special circumstances yielded some unequivocal information. As the numbers of fishes increased, supplementary collections were made, but these cannot be depended upon to show the relative numbers of each species, except locally, in a few cases.

The ditch was still almost devoid of fishes after two weeks (Table 3). Over half of the 57 fishes of all species then counted were found in the westernmost 100 feet of ditch,

TABLE 2.—FISH IN WESTERNMOST 1,100 FEET OF A 5,600-FOOT DITCH. KILLED BY THE MAY 10 APPLICATION OF DIELDRIN PELLETS

Species	Number	Pounds
Sea catfish (*Galeichthys felis*)	1	—
Rainwater killifish (*Lucania parva*)	1	—
Marsh killifish (*Fundulus c. confluentus*)	1	—
Gulf killifish (*Fundulus g. grandis*)	635	—
Longnose killifish (*Fundulus similis*)	1	—
Broad killifish or variegated minnow (*Cyprinodon v. variegatus*)	214	—
Eastern mosquitofish or gambusia (*Gambusia affinis holbrooki*)	18	—
Sailfin molly (*Mollienesia latipinna*)	148	—
Striped mullet (*Mugil cephalus*)	635	104¾
White mullet (*Mugil curema*)	37	—
Irish pompano (*Diapterus olisthostomus*)	17	—
Spot (*Leiostomus xanthurus*)	26	—
Atlantic croaker (*Micropogon undulatus*)	8	—
Pinfish (*Lagodon rhomboides*)	13	—
Fat sleeper (*Dormitator maculatus*)	9	—
Emerald goby (*Erotelis smaragdus*)	6	—
Mapo (*Bathygobius soporator*)	6	—
Lyre goby (*Evorthodus lyricus*)	25	—
Esmeralda (*Gobionellus smaragdus*)	7	—
Spotfinned whiff (*Citharichthys spilopterus*)	8	—
Southern hogchoker (*Trinectes maculatus fasciatus*)	4	—
Toadfish (*Opsanus tau*)	4	—
Totals (22 species)	1,824	115¼

TABLE 3.—BIWEEKLY CENSUS ALONG 5,600 FEET OF MARSH DITCH AFTER A CATASTROPHIC MARSH-WIDE FISH KILL BY DIELDRIN

Weeks after Treatment	2	4		6		8		10		13	17
Species	Obs.	Obs.	Coll.[1]	Obs.	Coll.[2]	Obs.	Obs.	Coll.[2]	Coll.[3]	Coll.[3]	Coll.
Tarpon atlanticus[4]	—	—	—	—	—	—	—	—	—	—	17
Galeichthys felis	—	—	—	—	—	1	—	—	—	—	—
Stongylura marina[5]	2	8	—	9	—	4	10	—	—	—	—
Fundulus g. grandis	—	50	7	100–200	61	common	abundant	63	30	3	32
Fundulus c. confluentus	—	—	14	—	7	—	—	2	182	6	337
Fundulus similis	—	—	—	—	2	—	—	—	—	1	—
Cyprinodon v. variegatus	13	800–1000	10	1000–2000	495	abundant	tens of thousands	15	9	2	47
Gambusia a. holbrooki	—	—	3	—	17	—	—	—	2	16	63
Mollienesia latipinna	—	—	—	—	24	—	—	3	—	64	—
Mugil cephalus	28	33	—	53	—	—	18	—	—	—	—
Mugil curema	—	—	—	—	—	—	—	—	—	1	—
Diapterus olisthostomus	3	7	—	—	—	—	—	—	—	—	—
Sciaenops ocellata	—	—	—	1	—	—	—	—	—	—	—
Dormitator maculatus	—	—	—	—	2	—	—	—	—	—	—
Evorthodus lyricus	—	—	—	—	4	—	—	1	—	—	—
Sphoeroides spengleri[6]	1	4	—	7	—	26	—	—	—	—	—
Fiddler Crabs	10	64	—	25	—	20	12	—	—	—	—
Blue Crabs	1	none	—	none	—	none	none	—	—	—	—
Shrimps	—	—	few	—	—	—	—	—	—	—	—
Amphipods	—	—	few	—	—	—	—	—	—	—	—
Nudibranchs and Snails	—	common	abundant	abundant	—	abundant	abundant	—	—	—	—

[1] West end of ditch in algae. [2] West end of ditch. [3] East end of ditch. [4] Tarpon. [5] Atlantic needlefish. [6] Puffer.

where most likely they had entered with and were somewhat protected by the last tidal influx. Mullets, which had just entered the area, showed signs of distress, but only one dead fish, a mojarra [Irish pompano] was found; this later proved to be the last dead fish to be seen in the area. A single living blue crab was observed, the last to be seen alive in the area, i.e. during the 17-week observation period. It was undeniable that the fiddler crabs were all but annihilated. The most interesting fact of this date was the complete disappearance of the fish killed two weeks before.

By the fourth week there was a small but unmistakable increase in the numbers of broad killifishes, which were in small schools so that their numbers had to be estimated as each school was encountered. Each algal patch within the 1,100-foot ditch segment was exhaustively collected. The combined collection (Table 3) was significant mainly in revealing that marsh killifishes were moving into the ditch and that mosquitofishes were present. It must be recalled that this end of the ditch had maximal tidal flushing, but the concentration of small fishes within the algal masses causes one to wonder whether they were not in some way protected there from the poison. The possibility that the algal mass may either present a physical barrier to the circulation of the poison or function somehow as a detoxicant should not be overlooked. It was within these algal masses that the only amphipods and shrimp were found (Table 3) and on them that the nudibranchs were crawling. The latter appeared to be abnormally abundant and were represented by a considerable range in sizes, and together with snails continued to be abundant throughout the period of observation. In fact, there were no visible harmful effects on any mollusks, including snails, nudibranchs, tethyoids, and oysters.

By the sixth week the broad killifish was the predominant fish species in the marsh and was still increasing in numbers, and gulf killifishes were more in evidence. No fish seen showed any signs of distress.

By the eighth week, both observers agreed that for the first time the adjectives, common and abundant, were appropriately ap-

plied to gulf and broad killifishes, respectively, and the latter for the first time were found throughout the length of the ditch.

On the tenth week after treatment, tens of thousands of broad killifishes were entering the ditch from Indian River. Neither author had ever before seen so many broad killifishes anywhere, so that this may be taken as the peak in the repopulation of the marsh by this species. Reduction in predators may have been a factor in its abundance. In many places the entire ditch bottom for many yards was completely covered with broad killifishes moving eastward from Indian River. An increased proportion of gulf killifishes were interspersed with them. Our collections in no way reflect the abundance of broad killifishes, which were difficult to seine. By this time, the marsh killifish was evidently reestablished toward the eastern border of the marsh, where in general it is normally more common than toward the open waters of Indian River.

Fortnightly censuses were discontinued after the tenth week, since further quantitative additions to the fish population could not have been recognized. By the thirteenth week, however, mullets were present for the first time far back from Indian River. The collections of the thirteenth (August 10) and seventeenth (September 9) weeks, both made in the easternmost marginal ditch, are notable for containing six supposedly larvivorous fish species. In the last collection, the inclusion of small tarpon (*Tarpon atlanticus*) ranging from 22 mm. to 35 mm. in standard length is of special interest, not only because these are smaller than any reported to be extant in collections (Breder, 1944; Simpson, 1954), but because they must have recently entered from Indian River. Of the larger fish species enumerated in Table 3, nothing need be said except that they are forms that move in and out with the tide. The complete absence of snook (*Centropomus undecimalis*) from the treated area, however, may be significant, as this species was taken in ditches several miles away from the treated area on nine dates distributed within the period covered by the posttreatment observations. Each of 20 species of fish other than those repopulating the treated area occurred in from one to three of the snook collections, but except for the mangrove or gray snapper (*Lutjanus griseus*), the spotted squeteague (*Cynoscion nebulosus*), the sheepshead (*Archosargus probatocephalus*), and the black drum (*Pogonias chromis*), each occurring in one collection, they were of no known economic importance. In 1956–57, the area was greatly altered by reditching and filling and finally by road construction, precluding further conformable observations.

DISCUSSION

Although the magnitude of the kill is less significant than the fact that it was substantially complete, its estimation is nevertheless of some interest. The areas sampled were in our opinion sufficiently representative of the whole marsh to warrant the following extrapolations.

The total weight of dead fishes recovered from the 1,100-foot ditch segment (Table 2) was substantially equivalent to that of the total kill there, but the total number killed, including diminutive unrecovered specimens, was most likely of the order of twice the number retrieved. On the bases of fish kill in the 1,100-foot segment and total linear feet of ditching, the kill over the entire area treated was 18.5 tons. Based on the kill in the 200-foot segment (Table 1), it was 32.7 tons. A minimum over-all kill of 20–30 tons is doubtless a conservative estimate for these reasons: the 1,100-foot ditch segment is exposed, with minimal cover and forage, the weight of fish taken from the 200-foot segment was less than that of the tota! kill there, and an appreciable pond acreage was not taken into account in making the estimate.

On the basis of the actual number of fishes (1,824) recovered from the 1,100-foot segment, the total number killed throughout the area treated was 587,000 individuals, but a more likely minimum estimate is twice this number, or 1,175,000. It is pertinent to mention that these figures refer merely to the ditches within the area

concerned and not to its devious and extended shore line along Indian River. Sufficient man power was not at hand to evaluate effects on fishes of the adjacent Indian River shallows, but these effects were enough to attract sharks (seen from the air moving in on the incapacitated fishes), and the shores were so littered with dead fishes as to cause unfavorable comment among local commercial and sport fishermen. Finally, from the unexpected virtual absence of dead and dying fishes, together with the paucity of living fishes in the treated marsh during the second and succeeding weeks after the catastrophic kill, one is tempted to speculate that a sizable portion of the inshore fish population was destroyed.

The time order of response to the toxic stimulus among fish species was roughly as follows: mullets (*Mugil*), mojarras (*Diapterus*), and snook (*Centropomus*), then killifishes (*Cyprinodon* and *Fundulus*), sailfin mollies (*Mollienesia*), and mosquitofishes (*Gambusia*), and finally, gobioid fishes (*Dormitator, Erotelis, Evorthodus,* and *Gobionellus*). This sequence appeared to be partly a function of size, yet even the smallest mojarras were quick to succumb. No species, as such, was spared by the dieldrin, but although killifishes littered the bottom on May 11, they still had a few small living representatives in the same area on that date. Whether these had recently entered from Indian River or were authentic survivors could not be established, but the former seems more likely in view of their general absence farther eastward in the ditch, unless they had found a sanctuary within the masses of algae (*see* above).

Field observations on the toxicity of dieldrin to fishes have been few and casual. Ginsburg and Jobbins (1954) noted "many dead fishes" on salt marshes after dieldrin was applied at 0.2 pound of active ingredient per acre. Dieldrin at 0.25 pound per acre "practically eliminated" fishes from freshwater ponds (Mathis and Quarterman, 1953), suggesting that the Hutchinson Island kill might have proven just as extensive at one-fourth the dose used.

From bio-assays of dieldrin with the fathead minnow (*Pimephales promelas*), Tarzwell and Henderson (1957) determined the median tolerance limit (TL/m = concentration killing 50 per cent of the fish) after different time intervals. With dieldrin–attapulgus clay suspension, their 96-hour TL/m values ranged from 0.023 to 0.036 p.p.m., dieldrin being more toxic in hard than in soft water. For the 1-pound-per-acre application on Hutchinson Island, the equivalent concentrations in p.p.m. of dieldrin, assuming 100 per cent release of the active ingredient, would be 0.4 p.p.m. (in 1 foot of water), 0.2 p.p.m. (in 2), 0.13 p.p.m. (in 3). Actual concentrations and TL/m values would, of course, be conditioned by the brackish water, tide, run-off from pellet-strewn high ground, and rate of release of the toxicant.

SUMMARY AND CONCLUSIONS

Two thousand acres of Florida east-coast tidal marsh, traversed by 354,000 linear feet of ditches, were treated with dieldrin pellets that were air-disseminated at one pound per acre, to destroy sandfly (*Culicoides*) larvae.

The fish kill was substantially complete. The minimum immediate over-all kill throughout the marshes, exclusive of the Indian River shore line, computed by extrapolation of the kill data of an 1,100-foot and a 200-foot ditch segment, respectively, was 20–30 tons of fishes, or about 1,175,000 fishes, of at least 30 species.

Mollusks (snails, nudibranchs, tethyoids, and oysters) seemed to be unharmed by dieldrin. Crustaceans were virtually exterminated throughout the area. The entire aquatic crab population was apparently destroyed, and the fiddler crabs, all but annihilated, survived temporarily only in patches of marsh evidently missed by the pellets.

The larger game and food fishes succumbed most rapidly, larvivorous fishes next, and gobioid fishes last. Crabs set upon and destroyed the moribund fishes, but next day were dead themselves. Snails continued to devour fish carcasses. After two weeks, no trace remained of the litter of dead fishes.

A biweekly posttreatment fish census was taken along a 5,600-foot ditch traversing the marsh; enumerations and estimates of the numbers of each species encountered were supplemented by sampling collections. The census was abandoned when progress in repopulation ended its dependability. Repopulation by fishes began slowly about 4 weeks after the kill, was undeniable at 6 weeks, considerable by 8, and climactic at 10. It was initiated by the broad killifish (*Cyprinodon v. variegatus*), the dominant invader, and included record minimum-sized tarpon by the seventeenth week, but large-sized fish of such species as snook were absent, perhaps significantly.

The general absence of dead and dying fishes and the scarcity of living fishes in the marsh after 2 weeks and later suggests that much of the fish population commuting between the marsh and adjacent inshore shallows of Indian River was destroyed.

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THE REMOVAL METHOD OF POPULATION ESTIMATION[1]

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The removal method of population estimation has been used for estimating small-mammal populations in a specified region for the North American Census of Small Mammals (Calhoun, 1948–51), as well as in other programs where a certain number of kill traps are set over several trapping periods.

The assumptions that underlie this method of estimation are:

1. The population must be essentially stationary, i.e., the joint effect of birth rates, death rates, immigration, and emigration must be negligible during the period of trapping.

2. The probability of capture during a trapping is the same for each animal exposed to capture.

3. The probability of capture remains constant from trapping to trapping, i.e., the animals do not become trap shy; also trapping conditions remain the same (constant trapping effort and relatively constant climatic conditions).

Just how well the method might apply if these assumptions were met in practice has been studied and presented in a technical statistical evaluation by Zippin (1956), who also looked into the validity of these assumptions. The present paper represents a general nontechnical review of these findings, as well as some additional results that are of interest to ecologists. No proofs will be given, and some of the results will be in the form of opinions.

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[1] From the Department of Biostatistics, The Johns Hopkins University School of Hygiene and Public Health, Baltimore, Maryland. Department Paper No. 315. This work was done under Navy Contract Nonr-248(16).

Figures 2 and 3 in this paper are reproduced from *Biometrics*, volume 12, page 163, 1956, with the permission of the editor of that journal.

METHOD OF ESTIMATING POPULATION SIZE

If we may think of a trapping program in which the same number of traps are set over several nights of trapping, according to the assumptions listed above, it is expected that the number caught and removed the first night will exceed the number caught and removed the second night. In general, then, as the population becomes depleted it is expected that the size of catch will decline from night to night.

There are several ways in which actual observed catches may be treated in order to obtain estimates of the original population size, as well as estimates of the constant probability of capture assumed by the method.

Hayne (1949) has suggested drawing a graph that plots the size of catch during a given trapping against the total number of animals previously captured. A straight line drawn by eye through the plotted points will cut the horizontal axis (which is the axis giving the number previously captured) at a point that represents the estimate of population size. This method is demonstrated in Fig. 1, where successive catches of 165, 101, and 54 are used. The regression estimate of population size in this case is shown to be 405 animals. The probability of capture per trapping is estimated by the slope of the line and is 0.41 for these data. This procedure is easy to employ; however, where the points do not fall neatly into a straight pattern, individuals will differ in their eye-fitted lines and will encounter considerable variability in the resulting population estimates.

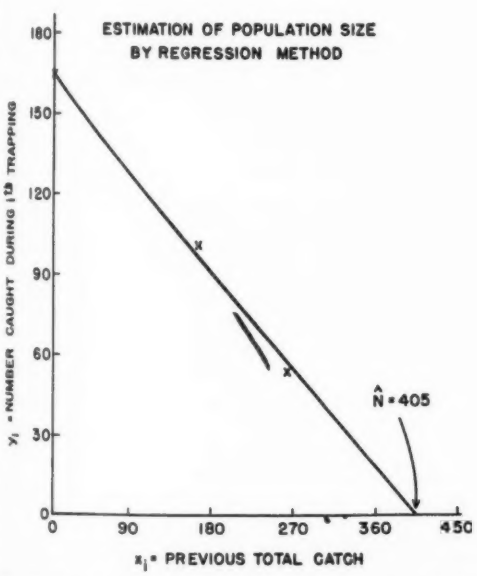

FIG. 1. Population estimation by regression method.

A second method, which fits the line to the points, the method of least squares (*see* Dixon and Massey, 1951), has been shown by Zippin (*op. cit.*) to be a satisfactory procedure. However, it requires a considerable amount of time to carry out without the aid of an automatic computing machine.

The recommended method of estimating population size from data collected in a removal program, employing constant trapping effort, is the multinomial method. This method has optimum statistical properties and, with the aid of specially prepared charts, allows a very rapid estimate of population size to be obtained. The following steps are required:

I. Case of two trappings

$$\hat{N}=\frac{y_1^2}{y_1-y_2}$$

where $\hat{N}$ is the estimate of population size, and y_1 and y_2 are the numbers of animals captured during the first and second trappings, respectively.

The estimate of the probability of capture during a single trapping is

$$\hat{p}=\frac{y_1-y_2}{y_1}.$$

II. General case of k *trappings*

1.

a) Calculate

$$T=\text{total catch}=\sum_{i=1}^{k} y_i=y_1+y_2+\ldots.+y_k.$$

b) Also find

$$\sum_{i=1}^{k}(i-1)y_i=(1-1)y_1+(2-1)y_2+(3-1)y_3+\ldots\ldots+(k-1)y_k.$$

In the above, sigma denotes the process of summation and y_i is the number of animals captured during the i^{th} trapping so that, in

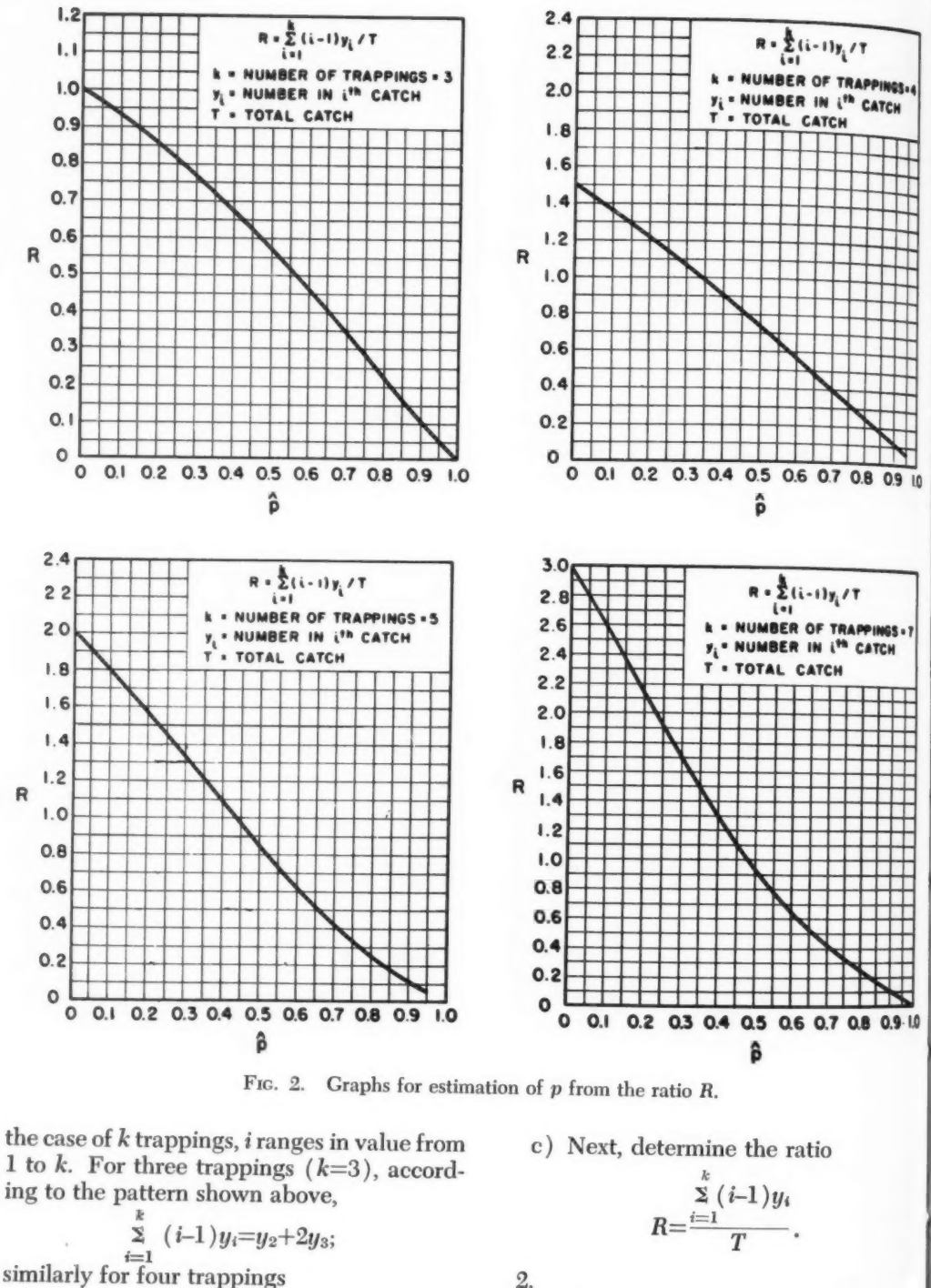
R = Σ (i-1)y_i / T
k = NUMBER OF TRAPPINGS = 3
y_i = NUMBER IN i^th CATCH
T = TOTAL CATCH
R = Σ (i-1)y_i / T
k = NUMBER OF TRAPPINGS = 4
y_i = NUMBER IN i^th CATCH
T = TOTAL CATCH
R = Σ (i-1)y_i / T
k = NUMBER OF TRAPPINGS = 5
y_i = NUMBER IN i^th CATCH
T = TOTAL CATCH
R = Σ (i-1)y_i / T
k = NUMBER OF TRAPPINGS = 7
y_i = NUMBER IN i^th CATCH
T = TOTAL CATCH
R
p̂

FIG. 2. Graphs for estimation of p from the ratio R.

the case of k trappings, i ranges in value from 1 to k. For three trappings (k=3), according to the pattern shown above,

$$\sum_{i=1}^{k} (i-1)y_i = y_2 + 2y_3;$$

similarly for four trappings

$$\sum_{i=1}^{k} (i-1)y_i = y_2 + 2y_3 + 3y_4.$$

c) Next, determine the ratio

$$R = \frac{\sum_{i=1}^{k} (i-1)y_i}{T}.$$

2.

a) If k, the number of trappings, is 3, 4, 5, or 7, refer to the appropriate chart in

Fig. 2 to obtain $\hat{p}$, the estimated probability of capture during a single trapping, corresponding to the R value calculated in step 1. The estimated proportion of the population captured throughout the trapping program is $(1-(1-\hat{p})^k)=(1-\hat{q}^k)$ where $\hat{q}=1-\hat{p}$. Values for $(1-\hat{q}^k)$ corresponding to calculated R values may be obtained directly from Fig. 3 without first finding $\hat{p}$.

b) Divide T by $(1-\hat{q}^k)$, the estimated proportion of the population captured, as obtained from Fig. 3. This gives $\hat{N}$, the estimate of population size.

For k other than 3, 4, 5, or 7, $\hat{p}$ and $\hat{q}$ may be obtained by solving the following equation:

$$R=\frac{\hat{q}}{\hat{p}}-\frac{k\hat{q}^k}{(1-\hat{q}^k)}.$$

N is again estimated by

$$\hat{N}=\frac{\text{total catch}}{\text{estimated proportion of population captured}}=\frac{T}{(1-\hat{q}^k)}. \quad (1)$$

The multinomial method is superior to Hayne's rapid method of fitting a regression line by eye since, with the aid of the graphs in Figs. 2 and 3, it is at least as fast and does not involve subjective estimation. A least-squares regression gives estimates that are as good as multinomial estimates; however, this method requires considerably more time to calculate than the multinomial estimate made using the graphs. The regression method may be recommended when the graphs are not available.

STANDARD ERROR OF MULTINOMIAL ESTIMATES OF POPULATION SIZE

Even if the assumptions of the removal method were to hold exactly in practice, an estimate based on a sample of catches would not be expected to agree exactly with the actual population size. This variability of estimates about the quantity the value of which is desired must be taken into consideration when using the sample value, i.e., estimate based on trapping results, as a guide to the population value. A measure that takes this into account is the standard error of the estimate. Under the theory of the normal frequency distribution, only one time in three will an estimate $\hat{N}$ be farther away from the true value N by an amount greater than one standard error. Only one time in twenty, if the theory applies, will the difference be greater than two standard errors. Thus, armed with the above knowledge, if the standard error of an estimate is known, amounts equal to one or two standard errors may be added to and subtracted from the estimate to obtain limits within which one has either 68 per cent or 95 per cent confidence of enclosing the desired population value.

The formula for the standard error of $\hat{N}$, the estimate of the population size, is approximately

$$\mathrm{SE}(\hat{N})=\sqrt{\frac{\hat{N}(\hat{N}-T)T}{T^2-\hat{N}(\hat{N}-T)\dfrac{(k\hat{p})^2}{(1-\hat{p})}}}. \quad (2)$$

$\hat{N}$ and T have their usual meaning, k represents the number of trappings, and $\hat{p}$, the estimate of the probability of capture during a trapping, is obtained from Fig. 2.

The standard error of $\hat{p}$ is calculated from the formula

$$\mathrm{SE}(\hat{p})=\sqrt{\frac{T(\hat{p}\hat{q})^2}{T^2\hat{q}-\hat{N}(\hat{N}-T)(k\hat{p})^2}}. \quad (3)$$

For example, assume the following catches in a 3-night trapping program (the same as used in demonstrating Hayne's method):

$$y_1=165,\ y_2=101,\ y_3=54$$

$$R=\frac{\sum_{i=1}^{k}(i-1)y_i}{T}=\frac{y_2+2y_3}{y_1+y_2+y_3}=\frac{209}{320}=0.65$$

From Fig. 2, R of 0.65 corresponds to $\hat{p}=$

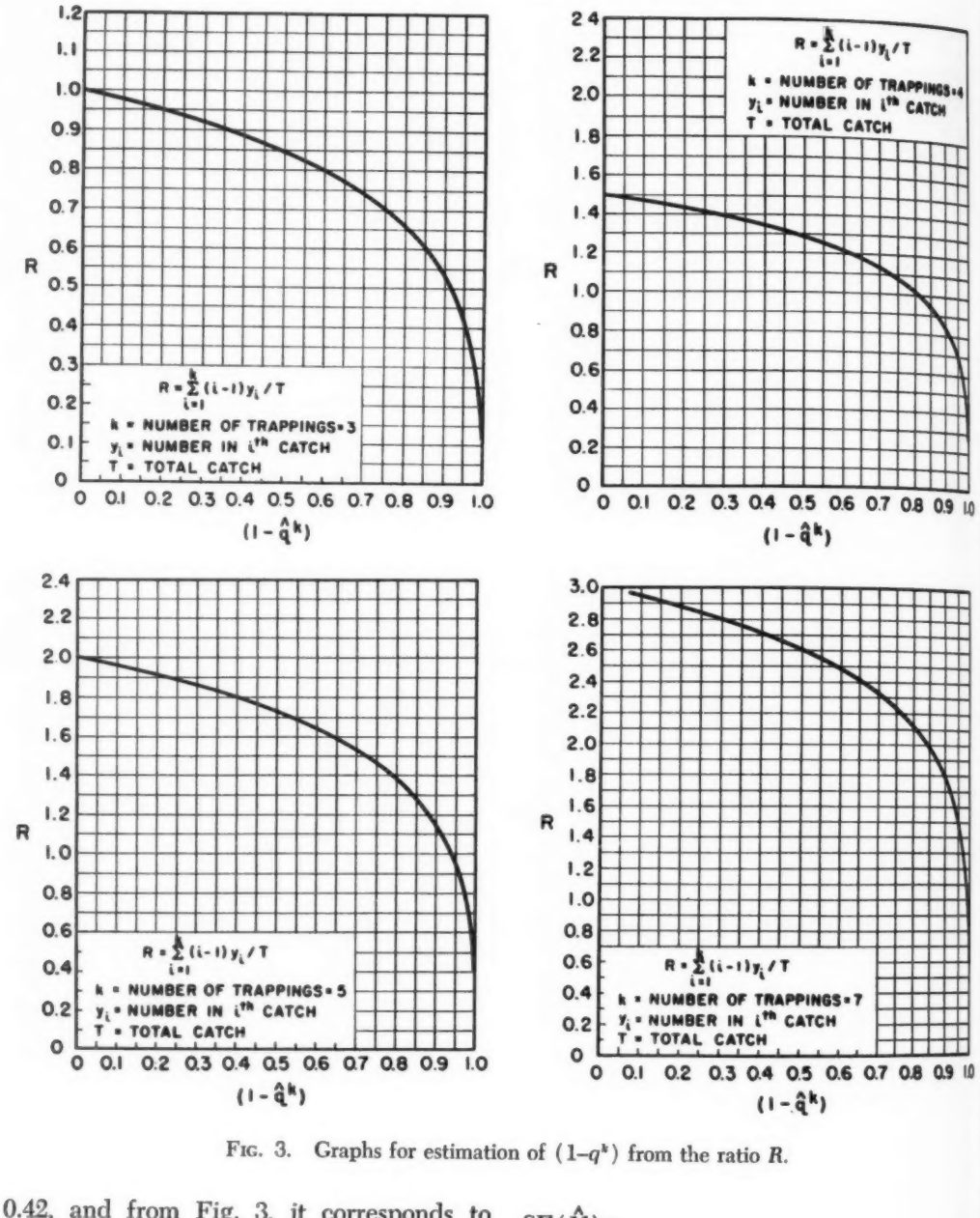
R = Σ (i-1)y_i / T
k = NUMBER OF TRAPPINGS = 3
y_i = NUMBER IN i^th CATCH
T = TOTAL CATCH
R = Σ (i-1)y_i / T
k = NUMBER OF TRAPPINGS = 4
y_i = NUMBER IN i^th CATCH
T = TOTAL CATCH
R = Σ (i-1)y_i / T
k = NUMBER OF TRAPPINGS = 5
y_i = NUMBER IN i^th CATCH
T = TOTAL CATCH
R = Σ (i-1)y_i / T
k = NUMBER OF TRAPPINGS = 7
y_i = NUMBER IN i^th CATCH
T = TOTAL CATCH
R
(1 - q̂^k)

FIG. 3. Graphs for estimation of $(1-q^k)$ from the ratio R.

0.42, and from Fig. 3, it corresponds to $(1-\hat{q}^k)$ of 0.80. Therefore,

$$\hat{N}=\frac{T}{(1-\hat{q}^k)}=\frac{320}{0.80}=400.$$

From equation (2) the standard error of $\hat{N}$ is

$$\mathrm{SE}(\hat{N})=\sqrt{\frac{(400)(400-320)(320)}{(320)^2-(400)(400-320)\dfrac{(3\cdot 0.42)^2}{(1-0.42)}}}=26.3.$$

The 95 per cent confidence limits for the population size are therefore 347 to 453, i.e., $400\pm 2(26.3)$.

The standard-error formula used above is satisfactory for populations of size 200 or more and when 90 per cent or less of the population is captured. For populations of less than 200 but greater than 50, in which the assumptions are assumed to hold reasonably well, the above method provides approximately 90 per cent confidence limits rather than 95 per cent limits.

PLANNING OF A PROGRAM

The theoretical precision of a population estimate is dependent mostly upon the proportion of the population expected to be captured over the entire trapping program and is only slightly affected by the number of trappings carried out. The total number of units of trapping effort, i.e., number of nights of trapping times the number of traps set each night, determines the proportion of the population expected to be captured. Thus, 100 traps set for eight nights are expected to capture roughly the same proportion of the population as 200 traps set over the same area for four nights. Therefore, in planning a trapping program involving a fixed total number of units of trapping effort and where infiltration of animals from nearby areas is expected to be negligible, the experimenter should employ the trapping schedule that is most economical. Where infiltration is sizable, a short intensive program is indicated.

PRECISION OF THE METHOD

The estimates of population size based on data from a removal-trapping program are not expected to be very close to the actual population value unless large proportions of the population are captured. Table 1 shows the proportion of the population that must be captured in order to reduce the coefficient of variation (ratio of the standard error of $\hat{N}$ to the population size) to specified levels.

The interpretation of some of the values of the table is as follows: For N=200, 55 per cent of the population must be captured to have a coefficient of variation of 30 per cent, i.e., to have a two-thirds chance that an estimate from this set of catches will be within 30 per cent of the actual population size; for a population of size 100,000, to have a two-thirds chance of being within 10 per cent of N, 20 per cent of the population must be captured. It is seen that for reasonably small populations, if the theory actually holds, very substantial segments of the population must be trapped in order to obtain fairly precise estimates of population size. The removal method is of definite value in situations where it is desirable to reduce a population sharply, as in the case of crop-damaging rodents, as well as to obtain a precise estimate of the original population size. This method may also be used to detect substantial changes in the density of animal populations.

TABLE 1.—PROPORTION OF TOTAL POPULATION REQUIRED TO BE TRAPPED FOR SPECIFIED COEFFICIENT OF VARIATION OF $\hat{N}$

N	Desired Coefficient of Variation (Per Cent)			
	30	20	10	5
	Proportion (to nearest 0.05) of Population to be Captured (in 100 or Fewer Trappings)			
200	0.55	0.60	0.75	0.90
300	0.50	0.60	0.75	0.85
500	0.45	0.55	0.70	0.80
1,000	0.40	0.45	0.60	0.75
10,000	0.20	0.25	0.35	0.50
100,000	0.10	0.15	0.20	0.30

SPECIFIC EFFECTS OF FAILURES IN THE BASIC ASSUMPTIONS

A decrease in the average probability of capture from one trapping to the next will occur when the probability of capture differs from animal to animal or when climatic or other factors decrease the activity of the animals during the course of the experiment. A removal estimate, made using data obtained under these conditions, will be expected to underestimate the population size. Table 2 gives the percentage by which $\hat{N}$ is expected to underestimate the actual population value in a 3-catch trapping program when the average probability of capture declines by a given amount between successive trappings.

TABLE 2.—EXPECTED PERCENTAGE UNDERESTIMATION OF N BY 3-CATCH REMOVAL ESTIMATE WHEN PROBABILITY OF CAPTURE ON SUCCESSIVE TRAPPINGS DECREASES BY CONSTANT AMOUNT

Prob. of Capture on First Trapping	Absolute Decrease in p on Successive Trappings				
	0.01	0.02	0.03	0.05	0.10
0.1	47.4	65.7	75.3	85.2	—
0.2	15.7	27.6	37.3	51.4	71.6
0.3	6.1	12.0	17.4	26.9	45.7
0.4	2.8	5.6	8.4	13.9	26.6
0.5	1.4	2.8	4.2	7.2	14.8
0.6	0.7	1.4	2.2	3.7	7.9

Similarly, increasing activity of the animals, perhaps the result of unrest due to meteorological conditions or depletion of food supply, may increase the probability of capture from trapping to trapping. In such a situation, the removal method will be expected to overestimate the population size.

If the number of animals subject to capture increases between trappings, the catches will be larger than would have been observed without an increase in the population size. The estimate of population size from these data will be expected to be greater than N_1, the number of animals present at t_1, the time of the first trapping. If the second and third trappings are scheduled for times t_2 and t_3, let N_2 and N_3 represent the size the population would have attained at those times in the absence of a trapping program. The rate of increase in population size, as well as the intensity of trapping, determines the expected amount by which the original population size will be overestimated from trapping data.

Let us consider a situation in which there is a constant factor by which the exposed number of animals changes between trappings. Table 3 gives values of expected estimates of population size (relative to N_1) when exposed populations, increasing by a constant factor, s, between successive trappings are subject to given probabilities of capture for three trappings. The right-hand column in the table gives the size of population, relative to N_1, that would have existed at time t_3 if no trapping had taken place.

If the population is increasing, perhaps instead of desiring the population size at the beginning of trapping, one might want $\hat{N}$ to give some estimate of the size that the population was destined to assume during the trapping program. Table 3 shows that, if the rate of increase between trappings is 20 per cent or less, the probability of capture should be at least 0.4, in order that the estimate should be expected to have a value intermediate between the original population size and the population that would have existed at the time of the third trapping, had the trapping program not been executed. A probability of capture of less than 0.4 would be expected to result in an overestimation of the potential population size at time t_3.

TABLE 3.—EXPECTED VALUES OF $\hat{N}/N_1$ WHEN POPULATION EXPOSED TO CAPTURE INCREASES BY FACTOR s BETWEEN SUCCESSIVE TRAPPINGS

$\hat{N}$ = Population estimate based on three trappings
N_1 = Population size at time t_1 (time of first trapping)
p = Probability of capture per trapping

s	p							N_3 (Pop. at Time t_3 without Trapping) $/N_1$
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	
1.01	1.10	1.04	1.02	1.02	1.01	1.01	1.00	1.02
1.02	1.22	1.09	1.05	1.03	1.02	1.01	1.01	1.04
1.03	1.37	1.14	1.08	1.05	1.03	1.02	1.01	1.06
1.05	1.82	1.25	1.13	1.08	1.05	1.03	1.02	1.10
1.10	10.00	1.66	1.30	1.18	1.11	1.07	1.04	1.21
1.20	—	5.00	1.88	1.43	1.25	1.15	1.09	1.44

VALIDITY OF ASSUMPTIONS

The precision of the removal method, as given earlier, represents an ideal situation in which there is complete conformance to the assumptions of the method. Failure of the assumptions may be due, for instance, to differences in catchability among the animals, variations from night to night in the number of unfilled sprung traps, which alters the trapping effort, and/or changes in environmental factors during the course of the experiment.

Zippin (*op. cit.*) used data from the North American Census of Small Mammals to look into the assumption of a constant probability of capture during a trapping program. Rodents of the genera *Microtus, Sigmodon, Peromyscus, Synoptomys,* and *Dicrostonyx* were represented in the 149 sets of data analyzed.

The catches were not separated according to genera which would have resulted in numbers too small to analyze. Chi-square tests, which were performed, in effect tested the hypothesis that the probability of capture was the same for all genera included in a program's catch and that this probability of capture remained constant over the entire trapping program. The chi-square test, which compares the size of the observed catches with the expected catches under the hypothesis tested, demonstrated statistically significant differences. The direction of the differences between the size of observed and expected catches was unsystematic, thereby suggesting no generally appreciable infiltration or decrease in the probability of capture during the programs studied. The significant chi-squares appear to be attributable to differences among the species comprising some of the catches, as well as additional factors (climate, food supply, etc.) which the theory assumes to remain constant throughout the trapping program but which, in practice, may change. To compensate for such possible departures from the theory on which the method of estimation is based, it was suggested that the standard-error formula, given earlier in this paper, might be multiplied by a factor of 1.2 to obtain a more realistic value. Additional studies are necessary to evaluate the conformance of data from a single species to the theory of the removal method.

COMPARISON WITH THE RECAPTURE METHOD

The recapture method of population estimation (Petersen, 1896; Lincoln, 1930) is widely used. It assumes that the proportion of marked animals in a catch is an unbiased estimate of the proportion of the population that has been marked up to that time. If, after the first catch, marked animals constitute 20 per cent of the population, but trap-shyness develops in these animals to the extent that they represent only 10 per cent of the next catch, then an estimate made from these recapture data will be twice the true population size. In making a choice between the removal and recapture methods, one important consideration is, therefore, the extent to which the assumptions required in the two methods are likely to hold in the population to be estimated. If both methods seem equally appropriate, then they may be compared on theoretical grounds in deciding which method to use. Such a comparison, to be published soon by the author, shows that the recapture method is superior, in terms of the precision of its estimates, to the removal method. The two trapping procedures may also be compared in terms of the precision of estimation per unit of cost involved in carrying out each type of program.

SUMMARY

The assumptions underlying the removal method of population estimation were reviewed and a graphical method of estimation (the multinomial method) was recommended and described.

If the assumptions of the method hold, the precision of a population estimate is primarily dependent on the proportion of the population captured, or the total number of units of trapping effort employed in the program, and relatively little on the number of trappings. Relatively large proportions of the population must be captured

in order to obtain precise estimates of population size.

Specific effects of failures in the basic assumptions, such as a decrease in the average probability of capture from one trapping to the next, and immigration into the trapping area during the trapping program, were described. Where the assumptions of both the removal and recapture methods of population estimation are met, the recapture method would be expected to give more precise results.

The assumption of a constant probability of capture was studied using data from the North American Census of Small Mammals. To compensate for an indicated departure from this assumption under actual trapping conditions, the standard-error formula for the estimate of population size should be inflated. An inflation factor of 1.2 was suggested for the data studied.

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BOOK REVIEWS

On the Trail of Vanishing Birds. By Robert Porter Allen. McGraw-Hill Book Company, Inc., New York, Toronto, and London. 1957. vii+251pp., 16 illus. $4.50.

This is an account of the author's connection with the efforts made by the National Audubon Society to protect birds, particularly rare and vanishing species. While his personal experiences cover about 25 years, he does outline important early Society work going back for more than 50 years.

The author gives autobiographical data mentioning the names of naturalists who helped guide his course: names that all of us oldsters hold in deepest respect.

In 1936, the Audubon Society inaugurated a series of special research projects beginning with the ivory-billed woodpecker, then in greatest danger, and continuing with the California condor, the roseate spoonbill, the whooping crane, and the American flamingo. Allen carried on the investigations for three of these: spoonbill, crane and flamingo; and in his account he tells graphically and often thrillingly of adventures, people, and birds from Yucatan to Aklavik. Although there were many disappointments, a very considerable measure of success attended his efforts in all three cases. Some of the narrative has been told before, and the author credits *Blackwoods Magazine* and *Audubon Magazine* for permission to repeat these parts. It is good to have all this excellent bird-conservation history between two covers.

One-half of the book is about the whooping crane. The small wintering flock was fairly safe on the Aransas Refuge in Texas. Where were these birds nesting? No wild nesting had been found since 1922. It took years of search by the author and many others to answer the question, but finally the nesting place of several pairs was discovered in the 17,300 square miles of wilderness comprising Wood Buffalo Park.

Perhaps North Americans know more about the long and special efforts to save the whooping crane than they do about similar work for spoonbills and flamingos, and the author tells us about this phase of his duties, blossoming forth as a good storyteller as well as a good naturalist. His local guide, referring to the prenuptial communal dance of the flamingos, said they were "commulating"—which seems a valuable addition to a wildlife vocabulary!

Incidentally, Allen's description of this affair is one of his best.

The concluding chapter tells of other vanished or vanishing birds: of the American egret, almost lost but the battle won, the Carolina paroquet, the great auk, the Labrador duck, the Eskimo curlew, the passenger pigeon, the heath hen, and the ivory-billed woodpecker. The California condor battle may be won for the moment.

The present bird dangers and probable tragedies of the neighbouring West Indies are attributed directly to the multiplication of the human population which is proceeding two and one-half times as fast there as anywhere else!

This reviewer was shocked to notice that all historical North American bird extinctions but two have occurred in the last sixty years. Will expanding mankind here and elsewhere leave room for birds? We have even reached the stage where photographers are a real danger and can break up an entire nesting colony.

One ornithological and logical inaccuracy is the statement that our sandhill cranes are divided into one species and three geographical races. Proofreading is good, but "nuchal" is spelled wrong. An index is always useful, even when chapter headings are a good guide as in this case.—HOYES LLOYD, Rockcliffe Park, Ottawa, Ontario.

A Laboratory and Field Manual of Ornithology. By Olin Sewall Pettingill, Jr. Burgess Pub. Co., Minneapolis. 1956. viii+379pp., illus. $5.00.

There is very little of a general nature that one can find to criticize in a work, such as the one under consideration, that has, as it were, evolved through "natural selection." Pettingill's manual has a history of almost 20 years. The first edition, in mimeoprint, appeared in 1939 as an outgrowth of a series of typewritten course outlines. In 1946, the second and expanded edition was published, and received wide use in North American universities. In preparation for the present revised edition, the author solicited suggestions from instructors and students all over the continent, and again incorporated new material. This book is, in the author's words, "intended as an aid to ornithological study at the college or university level." It "does not pretend to cover the ornithological field . . .; there is much more subject matter than can be included in any one course; it is to be expected that each instructor will adapt the manual to his particular needs by selecting sections in the order which seems most logical to him."

The chapter headings indicate the contents of this book. They are, in order of appearance: topography; feathers and feather tracts; anatomy and physiology; systematics; external structural characters; laboratory identification; plumages and plumage coloration; distribution; migration; field identification; bird ecology; bird communities; bird territory; bird song; mating; nests and nest building; eggs, egg laying and incubation; young and their development; parental care; and bird populations. At the end of each chapter there is a well-selected list of references. In addition, there are the following appendices: ornithological field methods; preparation of a paper; bibliographies pertaining more or less to ornithology; bibliography of life-history studies; selected bibliography of North American works on birds; books for general information and recreational reading; and current ornithological journals.

It is apparent, from the listing above, that all aspects of ornithology receive some attention. Wildlife managers should note, however, that this book is not a handbook for their purposes. The topics that are treated in greatest detail are those basic to ornithology *per se*—such as topography, pterylography, anatomy, physiology, and external structural characters. Other aspects of ornithology, which have traditionally been of great interest, such as distribution, migration, nests and nest building, and individual development, also receive emphasis. The sections on ecology and population dynamics are skeletal, but perhaps that is just as well in an introductory work.

For some topics, outlines of study procedure and of methods for presenting results are given. The outlines are useful as examples, but one would hope that their presence will not inhibit independent development of research plans. Ornithology, like any other science, is a dynamic discipline and, while the work of the future must have reference to what has been done before, it should not be restricted by the past.

As is proper in an introductory manual, there is full recognition of our imperfect understanding of certain features of avian life, such as migratory orientation. The need for further study of many topics is indicated, although it is notable and praiseworthy that none of them is treated so as to develop contentiousness. An air of unjustified finality may have unconsciously been lent to some subjects. For example, waterfowl workers, who have watched incubating females dampen their eggs with their breast feathers as they return from water, might dispute the statement: "In . . . waterfowl, hatching success is apparently related to the frequency with which their eggs are wetted by rainfall."

To those who share the reviewer's belief that it is essential to know the organism itself before attempting to unravel its relationships with its environment, there can be no doubt that mastery of the subject matter of this book would be an excellent beginning for any young ornithologist, whether he wishes to proceed toward a career in academic ornithology or one in the applied ecological field. —DAVID A. MUNRO, Canadian Wildlife Service, Ottawa, Ontario.

BRIEFER ARTICLES

EFFECT ON GROUSE POPULATIONS OF DDT SPRAYING FOR SPRUCE BUDWORM

Robert S. Hoffman, Reuel G. Janson, and Fred Hartkorn
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Montana Fish and Game Department, Great Falls and Missoula, Montana

Some forests of western Montana are infested with spruce budworm (*Choristoneura fumiferana*), which is controlled by aerial applications of DDT at the rate of 1 pound per acre. The effects of this treatment on the native grouse—*Dendragapus obscurus, Bonasa umbellus,* and *Canachites canadensis*—were unknown. It was supposed that such spraying might affect grouse: (1) through the consumption of DDT-poisoned insects by grouse chicks, or; (2) through food shortage occasioned by large-scale reduction in insects. The two factors could work together, since increased susceptibility of undernourished birds to direct poisoning was indicated by George and Mitchell (1947). However, observations on two broods of ruffed grouse showed no direct poisoning effects of DDT application of 5 pounds per acre (Adams, Hanavan, Hosley, and Johnston, 1949).

We are indebted to the following persons who assisted us in field work: Bert Goodman and Joseph Townsend, of the Montana Department of Fish and Game, and personnel of the Bitterroot, Beaverhead, Helena, and Lewis and Clark national forests. James B. Sammons and Dale Choukalos assisted the senior author in the field. The study was supported by the Wildlife Restoration Division, Project W-74-R-2, Montana Fish and Game Department, and by the U.S. Forest Service.

DESCRIPTION OF STUDY AREAS AND METHODS

The first phase of the study, determination of population density and brood size on sprayed and unsprayed land, was conducted in the Bitterroot Mountains. Two areas, about 118,000 and 51,000 acres in size, were sprayed with DDT in the summer of 1955 at the rate of 1 pound per acre. The closest boundaries of these areas were about 12 miles apart, and each was surrounded by unsprayed forest land. Previous counts of grouse, made along routes established in 1942 (Wright and Hiatt, unpubl. ms.) and walked again in 1946, 1949, and 1952–55, provided a comparison with 1956 findings, since the routes were located in both sprayed and unsprayed areas.

The relative-population-density index consisted of recording all grouse seen and of recording all broods while walking over a given mile of route. Nine routes, totaling 82 miles, were walked in 1956 in the two areas sprayed the previous year. Better than three-fourths of this total route length was well within, i.e., more than two miles from, the boundaries of the sprayed area, while the remaining mileage skirted the boundary at four locations. Similarly, nine routes, totaling 105 miles, were walked in the surrounding unsprayed area; less than ten miles of these came within two miles of the sprayed areas.

The second phase of the study, determination of age composition of grouse in the hunter bag, was carried out at checking stations set up in west-central Montana. These sampled grouse bags were from both sprayed and unsprayed areas. The size of areas sprayed during the summer of 1956, the first year of DDT application here, was as follows: Little Belt and Castle Mountains—254,000 acres; Big Belt Mountains—107,000 acres. The shortest distance between the edges of the two areas was over 30 miles. Control areas, unsprayed in 1956, included the Lewis Range, 50 miles north of the nearest sprayed areas, and portions of the Little and Big Belt mountains adjacent to the sprayed areas. In addition, unsprayed areas in the Garnet, Sapphire, and Bitterroot mountains of western Montana were sampled.

The relative proportion of young to old grouse, as determined by development of outer primaries and rectrices, in the kill from each area served as a sample of the population age composition and thus as a measure of juvenile mortality.

RESULTS

If the 1955 spraying in the Bitterroots had seriously affected grouse populations by causing mortality of adults or chicks, population density or brood size in 1955 and 1956 might be expected to show this, but such was not the case. The results of the field observations are summarized in Table 1.

TABLE 1.—POPULATION DENSITY AND PRODUCTION INDICES TAKEN ON AREAS SPRAYED IN 1955, AND CONTROL AREAS

Index	Area Sprayed in 1955	Unsprayed Area
Grouse per mile of census route		
1952–55	0.44	0.73
1956	0.80	0.29
Blue grouse brood size		
1952–54	3.00±.29 (N=15)	3.14±.39 (N=21)
1955	3.00±.63 (N=5)	4.20±1.11 (N=5)
1956	4.00±.50 (N=9)	2.67±.69 (N=9)
Broods : adult ratio		
1952–54	0.60	0.78
1955	1.0	0.56
1956	0.53	0.80

From these results, it may be seen that DDT spraying at the rate of 1 pound per acre did not cause such a marked change in grouse population, brood size, or brood numbers as to be evident in the year following spraying. Because the index to numbers is of limited accuracy and because of the small number of broods observed, this generalized conclusion is the best that can be offered. The population trends, of an increase in grouse on the sprayed area, and a decrease on the unsprayed area, may be real or may simply reflect the limitations of our methods. In any case, if grouse were adversely affected by the spraying in 1955, this result was by no means apparent at the time of our studies in 1956.

A final check on possible influence of the DDT-spraying operation was provided by bag check of grouse hunters. Our age ratios of grouse checked through stations in sprayed and control areas (Table 2) may be compared with ratios of 2.0 young per adult blue grouse, and 1.4 young per adult ruffed grouse, averages established over the period 1949–53 (Hartkorn, unpubl. ms.). Since the proportion of juvenile grouse from DDT-sprayed areas compared favorably with ratios from areas not sprayed, there is no reason to believe that juvenile mortality was increased by the DDT spraying.

TABLE 2.—AGE RATIO OF GROUSE IN HUNTER BAGS

Area	Species of Grouse	No. of Grouse		Juv. Per Adult	Per Cent Juv.
		Adult	Juv.		
SPRAYED AREAS					
Little Belt, Big Belt, and Castle Mts.	Blue	57	108	1.90	65
UNSPRAYED AREAS					
Little Belt, Big Belt, and Lewis Range	Blue	131	199	1.52	60
Garnet, Sapphire, and Bitterroot Mts.	Blue	18	29	1.61	62
	Ruffed	15	20	1.33	57

We believe these age ratios to be the best of three admittedly imprecise methods we employed. The data are quantitatively more adequate, and the distances between sprayed and unsprayed areas sampled reduce the possibility of significant movement between unsprayed and sprayed areas.

Blue grouse in particular are known to feed regularly on grasshoppers (Stewart, 1944; Wright and Hiatt, ms.), and some evidence on the effect of the DDT spraying on these insects was obtained in our study. Our technique of sampling was as follows: An area suitable for grasshoppers, with little understory vegetation, was selected, and several sweep lines were arbitrarily selected. Each line was covered with 50 sweeps of a standard insect net, and insects so taken were preserved in alcohol–glycerine for later identification. Catches were scanty in all of the samples, and showed no significant correlation with the pattern of DDT spraying. The great bulk of insects captured were grasshoppers, and observations in sprayed areas conclusively demonstrated that DDT applied at the 1-pound-per-acre rate did not materially reduce their numbers. At Canyon Creek Ranger Station on the Beaverhead National Forest, grasshoppers were observed to be very abundant on August 8, following the DDT spraying of the area in mid-July. Similarly, grasshoppers were extremely abundant on the South Fork of the Judith River in the Little Belt Mountains in mid-August, following DDT spraying.

SUMMARY

Following 1-pound-per-acre applications of DDT for spruce-budworm control, efforts were made to measure the effects on three species of grouse in Montana. Counts were made of adult birds and of broods before, during, and one year after spraying, and in sprayed and unsprayed areas. Hunter bags of grouse from sprayed and unsprayed areas were also sampled to obtain age ratios. The evidence from all sources, although not of a rigorous nature, agrees with the conclusion that DDT applied at the rate of 1 pound per acre to control spruce budworms is not immediately harmful to populations of "mountain" grouse. Grasshoppers, a staple in the diet of blue grouse, were not noticeably reduced in numbers by the spraying.

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A POSSIBLE OCCURRENCE OF AVIAN LEUKOSIS IN THE WILD TURKEY

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In June of 1957 a complete skeleton of a wild turkey (*Meleagris gallopavo*) was found approximately 10 miles north of Tallahassee in Leon County, Florida. The bones of this bird showed abnormal calcium deposits to an extensive degree (Fig. 1). The skeleton was mailed to Dr. A. O. Haugen, Leader of the Cooperative Wildlife Research Unit, Auburn, Alabama, for examination by the School of Veterinary Medicine at the Alabama Polytechnic Institute. Dr. W. E. Ribelin carefully examined the skeleton by radiographs and other means and concluded that the pathologic condition of the skeleton probably represents an atypical type of the osteopetrotic form of avian leukosis. It is atypical in that the metatarsi are not involved, nor is there any encroachment upon the cortex or marrow cavity of the bone. Dr. Ribelin conjectures that perhaps this may be the characteristic response of the wild turkey to this disease. The disease essentially is one of diffuse periosteal proliferation and ossification affecting most all of the long bones of the body as well as the pelvis. The possibility occurs that, had the disease affected the metatarsi as it typically does in domestic poultry, the turkey would have been so handicapped that it would have been destroyed by predators long before it reached the advanced stage indicated in Fig. 1. The skeleton was found intact, the bird apparently having died as a result of the osteopetrotic form of avian leukosis.

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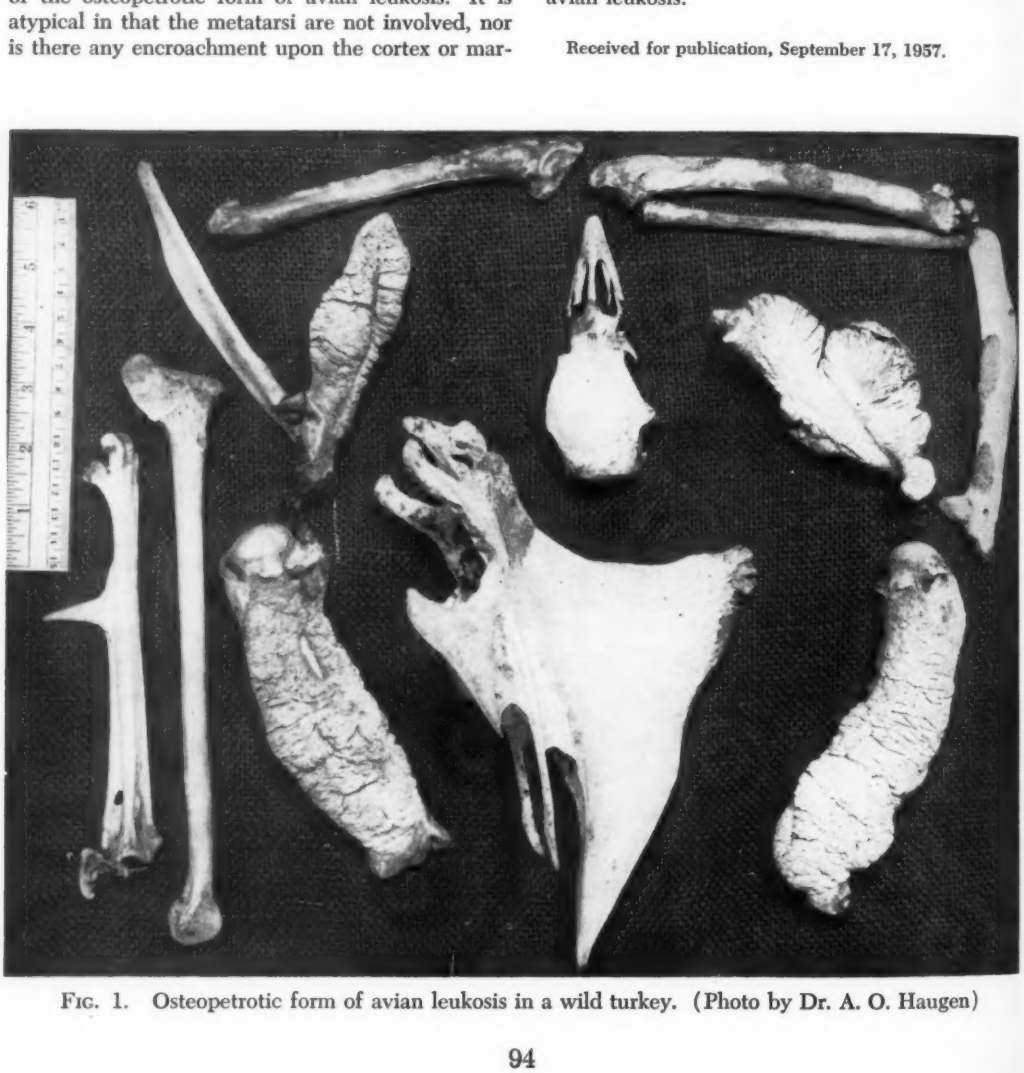

FIG. 1. Osteopetrotic form of avian leukosis in a wild turkey. (Photo by Dr. A. O. Haugen)

FIELD KEY TO GUARD HAIR OF MIDDLE WESTERN FURBEARERS

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A number of keys for identifying mammalian hairs have been published. Probably the most recent and refined of such publications is that by Mayer (1952. The hair of California mammals with keys to the dorsal guard hairs of California mammals. *Amer. Midl. Nat.*, 48:480–512) in which earlier papers are summarized. Because laboratory facilities and a microscope are required in order to utilize the above keys, they do not answer entirely the needs of the field biologist. A means of identifying hairs without a microscope is provided in the key presented in this publication. The key has been tested on Middle Western furbearers in the field and laboratory, with more than 85 per cent of the hairs being identified without difficulty. At least a dozen animals of each species of both freshly killed and museum specimens were examined. In each case, hair was taken from no less than five general locations on the specimen, depending upon the variability of the hair on a given animal.

There are two principal types of hair on the body of most mammals: the guard hair which is long, coarse, and often pigmented; and the underfur which is short, thin, often wavy, and less pigmented than the guard hair. This key is based upon the guard hairs, as they represent the most common sign left by an animal. Guard hairs can be found on sticks along well-used paths, on barb-wire where the animal passed under or through a fence, near feeding sites, on rocks, roots, bark, sharp surfaces, and splintered wood, or mixed with loose dirt in the bottom of a den entrance.

The effectiveness of the key is lessened when the normal sequence of colors of the guard hair is broken, or when the animals are immature or abnormally colored (albino or melanistic mutants). Because the hairs of domestic animals are so variable in color and size they have not been included.

In addition to the above difficulties, most mammals possess guard hairs that differ from one region of the body to another. These differences may be in size, in coloration, or in the combinations of colors to be found from the tip of the hair to the base. Although the key indicates the area of the body where a particular kind of hair can be found, this is not the only region on which this type may occur. On occasions, guard hairs from two different animals may appear to the unaided eye to be of the same color and size. By using several hairs from the same animal, the investigator may run through several different branches of the key and thus decrease the chance of error.

The true colors of hairs can be determined best by holding them against a light-blue background; a white, black, or brown background blends with several of the colors found in hairs, and makes use of the key more difficult.

KEY TO GUARD HAIRS

1. Tip black 2
   Tip not black 39
2. Only one color, black 3
   More than one color 8
3. Less than one inch long 4
   More than one inch long 5
4. Rigid, straight, high in luster ..... Spotted skunk (belly)
   Soft, curly, dull in color ..... Bobcat (tail)
5. Less than two inches long 6
   More than two inches long 7
6. Few or many delicate waves at base ..... Spotted skunk (back)
   Few large waves or straight at base ..... Striped skunk (belly)
7. Less than three inches long ..... Striped skunk (back)
   More than three inches long ..... Spotted skunk (tail)
8. Two colors only (from tip, black over white, black over brown, or black over tan) 9
   Three or four colors 22
9. Colors in two to five bands 10
   Colors in 8 bands ..... Fox squirrel (tail)
10. Colors in two or three bands only 11
    Colors in four or five bands only 18
11. Colors in two bands only 12
    Colors in three bands 17
12. Colors from tip: black over brown 13
    Colors from tip: black over white 14
13. Short black tip followed by long band of lustrous brown ..... Beaver (back)
    Black over brown ..... Bobcat (belly)
14. More than four inches long; coarse and with little or no wave ..... Striped skunk (tail)
    Less than four inches long 15
15. More white than black, thin and wavy ..... Opossum (back)
    More black than white, straight from tip to base 16
16. More than one inch long ..... Striped skunk (tail)
    Less than one inch long ..... Badger (front foot)
17. Colors from tip: black-white-black or black-brown-black ..... Woodchuck
    Colors from tip: black-tan-black ..... Cottontail (back)
18. Hair colors in four bands: from tip, black-white-black-white 19

Two colors in five bands: from tip, black-white-black-white-black ..... Woodchuck

19. Black tip less than one-half inch long; hair may have large waves near base 20
Black tip more than one-half inch long; hair straight 21

20. In large waves ..... Coyote (tail)
Not in large waves ..... Raccoon (back)

21. Color bands distinct ..... Gray fox (tail)
Color bands not distinct, blending Raccoon (back)

22. Three colors 23
Four colors: black-white-brown-gray Raccoon (back)

23. Three colors in three bands 24
Three colors in more than three bands 28

24. Color combinations from tip: black-white-brown ..... Raccoon (back)
Not as above 25

25. Color combinations from tip: black-white-gray ..... Cottontail or Jackrabbit
Color combinations from tip: black-brown-white 26

26. Less than three inches long 27
More than three inches long Striped skunk (tail)

27. Wavy at base ..... Opossum (groin)
Not wavy at base ..... Red fox (tail)

28. Three colors in four bands 29
Three colors in more than four bands 36

29. Color combination from tip: black-brown-black-gray ..... Cottontail (back)
Not as above 30

30. Color combination from tip: black-white-black-brown ..... Gray fox (back)
Not as above 31

31. Color combination from tip: black-white-black-gray 32
Not as above 34

32. Less than one inch long; wavy at base Bobcat (tail)
More than one inch long; not wavy at base .. 33

33. Less than two inches long .. Jackrabbit (back)
More than two inches long ..... Raccoon (back)

34. Color combination from tip: black-white-dark brown-light brown ..... Bobcat (back)
Not as above 35

35. Color combination from tip: black-white-brown (or gray) -white ..... Coyote (back)
Color combination from tip: black-white-brown-black ..... Woodchuck

36. Three colors in five bands; less than three inches long 37
Three colors in six bands; from tip, black-brown-white-brown-black-white; more than three inches long ..... Coyote (back)

37. Color combination from tip: black-white-black-brown-black 38
Color combination from tip: black-white-brown-white-brown (or gray) Gray fox (tail)

38. Less than one inch long ..... Fox squirrel (back)
More than one inch long ..... Woodchuck

39. Tip white 40
Top not white or black 51

40. Only one color, white 41
More than one color 48

41. Less than one inch long 42
More than one inch long 45

42. More than one-half inch in length; coarse and straight ..... Cottontail (belly)
Not as above 43

43. Short, fine, and very wavy ..... Opossum (belly)
Not as above 44

44. Less than one-half inch long ..... Weasel (belly)
More than one-half inch long ..... Bobcat (tail)

45. Less than two inches long 46
More than two inches long 47

46. Thin and tends to be wavy ..... Bobcat (belly) or striped skunk (back)
Straight ..... Jackrabbit (belly), striped skunk (belly), spotted skunk (back), or badger (back)

47. Less than three inches long .. Opossum (back), striped skunk (back), coyote (belly), or spotted skunk (tail)
More than three inches long; coarse Striped skunk (tail)

48. Two colors only 49
More than two colors; color combination from tip: either white-black-white-brown or white-brown-black-brown-white Badger (back)

49. Two colors in two bands 50
Two colors in three bands 53

50. Color combination: white over gray 51
Not as above 52

51. Less than two inches long Jackrabbit or cottontail (tail)
More than two inches long ..... Raccoon (belly)

52. Color combination: white over black Jackrabbit or cottontail (back or tail)
Color combination: white over dark brown Woodchuck (belly)

53. Color combination from tip: white-brown (or black) -white ..... Badger (belly or back)
Color combination from tip: white-gray-white ..... Raccoon (base of tail)

54. All yellow; less than one-half inch long Weasel (belly)
Tip brown 55

55. Only one color, brown 56
More than one color or shade of color 68

56. Less than one inch long 57
More than one inch long 59

57. Uniform shade from tip to base; does not shine; orange or reddish brown in color ..... Fox squirrel (belly)
Not of uniform shade; darker at tip; shines 58

58. Less than one-half inch long ..... Weasel (back, tail)
More than one-half inch long ..... Mink (back, tail)

59. Less than two inches long 60
More than two inches long 67

60. Thick, coarse, and shreds when broken ..... Woodchuck (tail)
Not as above 61

61. Dark brown; lustrous (shiny), as found in animals that live in water 62
Dark or light brown, not lustrous 64

62. Uniform chocolate-brown color 63
From chocolate brown at tip, grading into lighter brown at base ..... Mink (tail)

63. Usually more than one and one-half inches long ..... Beaver (back)
Usually less than one and one-half inches long ..... Muskrat (back)

64. Light or reddish brown 65
Chocolate brown; wavy ..... Raccoon (tail)

65. Light brown; dull in color (doesn't shine) 66
Reddish brown; shiny ..... Red fox (belly, back)

66. Wavy ..... Raccoon (tail)
Straight ..... Gray fox (belly)

67. Much darker at tip than at base ..... Red fox (tail)
About same shade for entire length ..... Badger (tail)

68. Two color bands, or with a distinctly different shade at base 69
More than two color bands 74

69. Color combination: brown over white 70
Not as above 73

70. More than one and one-half inches long 71
Less than one and one-half inches long 72

71. Tip tapers gradually and evenly ..... Beaver (belly)
Tip tapers abruptly ..... Mink (side)

72. Color combination: light brown over white ..... Beaver (belly)
Color combination: dark brown over white ..... Opossum (belly)

73. Color combination: light brown over gray; less than one and one-half inches long ..... Muskrat (belly)
Color combination: light brown over black; more than one and one-half inches long ..... Beaver (back)

74. Three color bands: from tip, reddish brown-black-white ..... Fox squirrel
More than three bands 75

75. Four color bands: from tip, dark brown-white-brown-white ..... Gray fox (tail)
Five or more color bands 76

76. Five color bands: from tip, brown or gray-white-black-brown or gray-black ..... Woodchuck (back)
Eight color bands, alternating black and brown bands ..... Fox squirrel (tail)

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RUFFED GROUSE ROOSTS AS A SPRING-CENSUS TECHNIQUE[1]

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During the period 1953 to 1955, the ruffed grouse (*Bonasa umbellus*) population in northwestern Wisconsin dropped sharply. It was noted that, coincident with the population decrease, the number of ruffed grouse winter roosts present after the snow melted in spring also sharply declined. Since deer have been censused using the pellet-group technique by many workers (Bennett, English, and McCain, 1940; McCain, 1948; Eberhardt and Van Etten, 1956), it seemed possible that ruffed grouse roosts might be counted along with the deer-pellet groups and provide a grouse population index. With this idea in mind, two areas were selected for a preliminary field trial in the spring of 1957 in northern and western Wisconsin. Because no further field work can be done by the writer on this technique at present, the preliminary findings are herewith reported.

The two areas comprised 4,006 acres in Rusk County, and 575 acres in Dunn County. The counts were made in April right after the snow left the ground and before the growth of herbaceous vegetation had started. The area in Rusk County is a solid block of forest cover consisting of aspen (*Populus tremuloides*) and other hardwoods (*Acer saccharum, A. rubrum, Tilia americana*) with scattered blocks of conifers. The area sampled in Dunn County is half wooded and half fields, with the woods generally confined to the hills and the farmed fields in the valleys. Scrub oak

[1] A contribution from P-R Project W-79. The author wishes to acknowledge the field assistance of Frederick V. Holzer and Russell Mattison and the editorial and statistical help of Ruth L. Hine and Donald R. Thompson.

(*Quercus* sp.), aspen and jack pine (*Pinus Banksiana*) are the major forest tree species.

A total of 457 plots in Rusk County and 337 in Dunn County of 1/50-acre size were searched. The plots in both areas were laid out in a regular grid so that the samples could be taken by a man walking in a straight line. A ruffed grouse "roost" was defined as any accumulation of four or more droppings made at night or in the daytime, including the scattered droppings resulting from tree roosting. Single droppings made while the birds were walking were thus eliminated. Only fibrous droppings formed while the birds are eating buds and twigs were tallied, since droppings made from herbaceous vegetation are soft and are not recognizable after the snow melts.

In the Rusk County area, 140 roosts were found on the 457 plots. Table 1 shows the frequency distribution for roosts found on these plots. In this table the distribution is compared to a theoretical Poisson, from which it differs significantly beyond the one per cent level. An inspection of the frequency distribution suggests that the poor fit is a result of a tendency for grouping of roosts. In Dunn County 90 roosts were found on 337 plots, and the same grouping of roosts noted.

TABLE 1.—COMPARISON OF ACTUAL ROOST FREQUENCY DISTRIBUTION WITH THE THEORETICAL POISSON, RUSK COUNTY

Number of Roosts	Actual Number of Occurrences	Theoretical Number of Occurrences
0	364	337.0
1	67	103.0
2	16	15.4
3	4	1.5
4	4	0.1
5	0	
6	1	
7	1	
	457	457

After the roost counts were obtained, the next problem was to see if these counts were at all related to actual population densities of grouse. To do this, it was necessary to make a number of assumptions based on general field observations made throughout the winter and spring of 1957. These assumptions, although crude, are nevertheless presented merely for purposes of illustration. First, a roost per-day-per-bird figure was needed. General field evidence indicated that an average of about two roosts per 24-hour period was approximately correct. The next statistics needed were the calendar dates between which these fibrous droppings were deposited. Crops from shot birds showed that green foods were taken right up to the first heavy snow on November 14. Thus, budding started at about this time. Droppings of cocks on drumming logs in spring showed that the birds went off the winter bud diet on about April 1. The total period when fibrous winter roosts were deposited on both areas was hence about 137 days. Using these empirical figures, the 140 roosts on 457 1/50-acre plots in Rusk County should be equal to a theoretical grouse density of 5.6 birds per 100 acres. Likewise, the Dunn County area should have 4.9 grouse per 100 acres. Since some grouse are dying all winter, these figures would represent the average winter population between November and April.

For comparison with these figures, the actual numbers of spring drumming cocks on the two areas were determined by a thorough search for all territories in April and May, 1957. The Rusk County area had a known population of 2.0 cocks per 100 acres, and corrected with the fall sex ratio, a total density of 3.9 per 100 acres. The Dunn County area had a known spring population of 4.5 cocks per 100 acres which, corrected by the fall sex ratios, gives a total density of 8.1 grouse per 100 areas in spring.

Comparison of the actual with the theoretical population density shows that the Rusk County roost count gave a fairly good estimate of the known spring population when the overwinter loss is taken into consideration. The Dunn County data, however, do not agree. Too few roosts were found.

It should again be emphasized that these conversion figures are merely presented for the purpose of providing a rough evaluation of this census technique and cannot be used without additional field research.

There are probably many reasons for this low population estimate from roosts in Dunn County. Since only about 50 per cent of the area is forested, there is a tremendous amount of woodland-field edge. The birds concentrate along these edges in their roosting and feeding. For example, I counted 13 roosts in one single plot along a field edge in a young jack pine thicket. This contagious distribution of groups increases the sampling difficulties. In addition, the large acreage of forest cover in oak has high populations of squirrels (*Sciurus carolinensis*) and deer (*Odocoileus virginianus*). These animals are continually digging and pawing for acorns all winter, turning over the forest litter and thereby covering roosts. The scrub oaks lose most of their leaves in spring, probably covering some groups. In the Dunn County study area, this roost-count method thus appears to be unworkable as a field population index.

To apply this technique in areas like Rusk County as an annual index, the number of days that budding takes place must be known. In some years it seems likely that early snows and/or cold temperatures may start budding as much as 10-20 days earlier than in years that are more mild. The date of the disappearance of snow in spring also will

affect the time birds will start feeding on willow catkins and various green-leaved herbs. This means that the feeding behavior of the birds in fall and spring. This statistic, corrected by the number of each year.

One possible method for eliminating the need for using a roost-per-bird-per-day figure would be to equate the spring cock density over a series of years to the average number of roosts found per acre in spring. This statistic, corrected by the number of days the birds were on a bud diet, should perhaps provide a usable population index.

This roost-group technique is relatively efficient in respect to man power in the field, since 10 to 14 plots can be run per hour if the plots are 2 to 4 chains apart. A total of 500 plots on a 4,000-acre area would take about 40 man-hours. Censusing the same-sized area using the King census (Leopold, 1933: 151) would probably take about 300-400 man-hours, while a complete search for all territorial males involves over 500 man-hours. If deer-pellet groups are being counted, the addition of a tally on ruffed grouse or spruce grouse (*Canachites canadensis*) roosts would require no additional effort. Based on our limited experience, this method—if used on solid forest blocks—appears to offer some promise as a workable population index for ruffed grouse.

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AN ECONOMICAL WAY TO NUMBER LINES, PLOTS, AND QUADRATS

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In the course of carrying on a number of field projects, some of short duration and others on a long-time basis, it becomes necessary to devise methods of marking one's study areas. The method employed needs to be practical, cheap, easy to carry out, and durable. The writer thought of the idea (I am sure not new) of utilizing old automobile license plates. These are discarded annually in large numbers in any given locality. They immediately become a ready source of both numbers and letters. All that is needed to complete the job is a good pair of tin snips, and you are in business to get as many numbers and letters as you may need.

We have a grouse study area that was set up in 1946 where we lettered the east and west lines and numbered the north and south lines on a grid system. Many of the numbers and letters applied in 1946 are still serving as markers on the lines.

The license plate lends itself well to such a project. Most of the plates have both numbers and letters, from which any desired series may be obtained. It is only a matter of obtaining a large series of plates. When ready for use, the letters and numbers may be nailed to posts, trees, or stakes with large-headed galvanized roofing nails.

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SHOTGUNS VERSUS RIFLES IN GRAY SQUIRREL HUNTING

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Since it is often possible and desirable to prescribe the type of firearm used on managed hunts, this paper compares the crippling losses, ammunition expenditures, and hunting success reported by 4,027 shotgun and rifle users on the Wheeler National Wildlife Refuge in the Tennessee Valley of northern Alabama. The data were procured through hunter interviews at checking stations and through questionnaires attached to permits during seven annual hunts. Questionnaire return, enforced by refusing permits on subsequent hunts to those who failed to return them, averaged 80.4 per cent. Hunter figures given in this paper include only those returning questionnaires.

The species hunted was the gray squirrel. *Sciurus carolinensis*, which had a high population in fairly mature bottomland hardwoods. The managed hunts were usually held in October, before

leaf fall, and dogs were not used. All shotgun gauges were allowed, but over 75 per cent of those used were 12-gauge, with size 6 the popular shot. All types of .22 rimfire ammunition were used, but the long-rifle solid-point bullet was the favorite.

CRIPPLING

During these seven hunts, 3,881 shotgunners reported bagging 13,904 gray squirrels and crippling an additional 2,108. This gives a ratio of 1 crippled to 6.6 bagged, or a crippling percentage of approximately 15.2.

During these same hunts, 146 riflemen bagged 377 squirrels and crippled 46. This gives a rifle-crippling ratio of 1 for 8.2 bagged, or a crippling percentage of 12.2.

While the percentage crippled by rifles remained fairly stable, shotgun crippling varied considerably with the individual hunt, sometimes dropping below the percentage crippled by rifles. This appeared to be due to hunting conditions. When leaf litter was dry and squirrels were wary and difficult to stalk, encouraging long-range shooting, the percentage crippled by shotguns rose sharply. When hunting conditioins were more ideal, with woods damp and squirrels easy to approach, the percentage crippled by shotguns was sometimes less than with rifles.

AMMUNITION EXPENDITURE

In reporting ammunition expenditure, hunters were cautioned to include only those shots actually fired at gray squirrels. Tabulations show 1.6 shotgun shells expended per squirrel bagged. Based on the current average price of 12 cents per round, this represents approximately 19 cents per squirrel taken for ammunition cost alone.

During these same hunts, riflemen fired 3.8 shots per squirrel bagged. With the current price of 1½ cents per round, this gives an average ammunition cost of a little less than 6 cents per animal.

COMPARATIVE SUCCESS

During the seven hunts for which rifle and shotgun data were kept separately, questionnaires returned from 3,881 shotgun users showed a total squirrel bag of 13,904, or 3.3 squirrels per man per hunt. For the same period, 146 riflemen bagged 377 squirrels, or an average of 2.6. During five of these hunts, 1952 through 1956, the hunting time spent by riflemen and shotgun users was computed independently. This showed that shotgunners averaged 1.6 hunting hours per squirrel bagged, while riflemen hunted 2 hours for each animal taken.

SUMMARY

Compared to 3,881 shotgun users on squirrel hunts on the Wheeler National Wildlife Refuge in Alabama, 146 men who used rifles reported that they hunted longer per animal bagged, fired more shots, took less game with a lower ammunition cost per squirrel bagged, and hunted with a possibly lower rate of crippling.

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THE COST AND EFFECTIVENESS OF CONTROLLING *MICROTUS* BY ZINC PHOSPHIDE

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The vole or field mouse (*Microtus californicus*) is an important consumer and destroyer of alfalfa, clover, and pasture grasses in the central valley of California. In many places the appearance of these rodents is sporadic, but in some parts of the Sacramento–San Joaquin Delta, where alfalfa is a major crop, they are almost continuously abundant. Ranchers may poison these mice as many as four or five times a year in heavily infested fields, and this is done at a considerable expense of time and money.

For many years zinc phosphide has been the standard poison for field mice in this region as it is elsewhere in the United States, Europe, the Soviet Union, and Japan. Despite the wide use of this material and the reliance placed upon it in the control of field rodents, we have a rather unsatisfactory picture of its actual effect on populations of wild mice. The U.S. Fish and Wildlife Service has made extensive field tests of zinc phosphide, but these reports are not published and are generally unavailable to the public. The most satisfactory analyses are those by Eadie (1950) and Hayne (1950), who tested various mechanical applications of poisoned bait.

The technique of poisoning field mice evaluated in the present paper is one used in many places in the world; it was studied in order to determine its cost, to evaluate its effectiveness, and to establish a standard with which other methods could be compared. With the cooperation of several ranchers, six populations of voles were studied. Each time poison was distributed, the mice were censused before and after in order to measure the result of the poisoning. Mice were captured in live traps, marked at each sampling by toe-clipping, and released. About 90 traps were used on 1-acre square plots. The population was calculated by the modification of the Lincoln Index proposed by Hayne (1949). In each census the population was esti-

mated from three ratios: that is, the mice were trapped for four consecutive nights.

Poisoning immediately followed the first census, and usually the second census began one to three days after poisoning. In two instances, the post-poisoning censuses were delayed for ten days; because the results were so different, they are discussed separately.

The tests reported here were made on the Craven-Huber Ranch in Sacramento County and on the Russell Young Ranch in Sutter County. It is a pleasure to acknowledge the generous cooperation of Isaac Craven and Russell Young.

RESULTS OF THE POISON TRIALS

The post-poisoning censuses (Table 1) indicate that zinc phosphide on rolled barley is a rather effective poisoned bait for field mice. On each occasion when a census was taken immediately after poisoning, the kill was found to be greater than 90 per cent; the mean reduction resulting from these four trials was 95.5 ± 1.3 per cent. Considering the usual effectiveness of most rodent poisons, this preparation could not be much more lethal.

TABLE 1.—SURVIVAL OF *Microtus californicus* IMMEDIATELY AFTER POISONING WITH ONE PER CENT ZINC PHOSPHIDE ON ROLLED BARLEY

Date of Poisoning	Habitat	Mice Per Acre Before	Mice Per Acre After	Number Killed
16 Nov. 1955	alfalfa	90	3	87
7 Jan. 1956	alfalfa	8	0	8
6 June 1956	irrigated pasture	86	7	79
30 Nov. 1956	irrigated pasture	86	2	84
Totals		270	12	258

The last two study plots (Table 2) were in the same rectangular field of 250 acres. These plots were close together, both had rather high populations of mice, and both were poisoned at the same time. These trials were conducted in the same manner as in the first four poison operations (Table 1), except that the census was not taken until ten days after the poisoning. The results are, however, conspicuously different: the mean reduction was only 82.4 ± 2.2 per cent in these last tests, a significantly smaller kill than that obtained in the first four trials.

TABLE 2.—SURVIVAL OF *Microtus californicus* TEN DAYS AFTER POISONING WITH ONE PER CENT ZINC PHOSPHIDE ON ROLLED BARLEY

Plot	Date of Poisoning	Habitat	Mice Per Acre Before	Mice Per Acre After	Number Killed
I	22 Dec. 1956	alfalfa	120	17	103
II	22 Dec. 1956	alfalfa	135	28	107
	Totals		255	45	210

Inasmuch as the only difference between these two sets of tests is the timing of the post-poisoning census, it seems likely that new mice invaded the last two plots after the poisoning and before the census. Reinvasion of small rodents into depopulated areas is a well-known phenomenon, and ten days is ample time for a small movement. Also, in this one instance the farmer delayed poisoning the remainder of the field after the study plots were baited, thus leaving a large unpoisoned area about 40 yards from the study plots. It is quite reasonable to assume, then, that the percentage kill was actually higher than the 82.4 per cent indicated by the census (Table 2), perhaps approximating the results obtained in the first four trials (Table 1).

Another line of evidence supports this assumption. At the conclusion of the first (pre-poisoning) censuses on these plots, there were known numbers of marked mice and calculated total populations. On Plot I (Table 3) there was a calculated population of 120 mice of which 56, or 47 per cent, were marked; and on Plot II there were 135 mice of which 92, or 68 per cent, were marked. In the populations surviving the poison, there should have been no significant change in the percentage of mice marked in the initial census. In other words, of the 17 mice remaining on Plot I (Table 3) there should have been eight (47 per cent) that were marked before poisoning; actually none of the previously marked mice were caught in the five days of the post-poisoning census. On Plot II, of the 28 surviving mice, there should have been 19 (68 per cent) previously marked individuals; but only seven were trapped in the five-day post-poisoning census. In the great departure from the expected ratios of marked individuals, it is quite apparent that mice moved into the study areas after the poisoning and before the completion of the post-poisoning census. The only place of a high mouse density at this time was the unpoisoned alfalfa 40 yards away.

At the risk of overworking the data, we can calculate the amount of invasion into Plot II—that is, the difference between the observed number of marked animals and the expected number indicates the number of mice that entered the plot after poisoning (Table 3). If the seven marked animals captured on Plot II represent 68 per cent of the surviving population, the total surviving population consisted of ten mice. If this was actually the case, we can substitute ten for 28 in Table 2 and the number killed would be 125 or 93 per cent, virtually the same percentage as obtained in the first four trials (Table 1). The close agreement of these independent estimates indicates beyond a doubt that the low kill obtained in the last two trials (Table 2) is an error, and furthermore that this error was caused by an invasion of mice into the poisoned plots. If we accept ten as the number of the original mice on Plot II after poisoning, then of the 28 animals present at that time, 18, or roughly two-thirds, were immigrants.

TABLE 3.—CHANGES IN PERCENTAGES OF MARKED MICE FOLLOWING POISONING

Plot	Before Poisoning			Ten Days After Poisoning		
	Mice Per Acre	Mice Marked	Percentage Marked	Mice Per Acre	Mice Marked Before Poisoning	
					Expected	Observed
I	120	56	47±5	17	8	0
II	135	92	68±4	28	19	7

Because of the highly lethal nature of this poisoned bait in the field, attempted improvements in the selection of poison or bait seem unnecessary. However, a more rapid means of distributing the bait would enable farmers to treat a large area quickly, increasing the effectiveness of the operation and reducing the labor cost.

THE COST OF POISONING MICE

The method of poisoning was the same in all instances. Rolled barley was the bait and the poison, zinc phosphide, was added to make a one per cent preparation. Mineral oil was the adhesive used. Vegetable oils tend to turn rancid in warm weather, causing a rapid deterioration of the effectiveness of the bait (Chitty, 1954:101). Farmers purchase this bait from agricultural commissioners for $5.35 for a 75-pound sack; the bait costs approximately $2.85, but a charge of $2.50 is made for the addition of the mineral oil and zinc phosphide. Large operators mix the bait themselves at a somewhat lower cost.

The amount of bait used depends upon the care of the operators and the density of mice, but it is usually between 5 and 15 pounds per acre. In the operation studied here, the application was 5 pounds of bait per acre, the cost of the prepared bait being about 6.3 cents per pound, the bait per acre cost approximately 31.5 cents per acre. Labor is the greater part of the total cost. Here again, the labor required is a measure of both the care in which the bait is distributed and the abundance of mice, but usually one man can distribute poison on slightly more than one acre in one hour, or ten acres in eight hours. At a farm laborer's wage of $1.25 per hour, the cost of labor in distributing the poisoned bait is $1.04 per acre, bringing the total cost of poisoning field mice to $1.35 per acre. This is the current expense of treating areas where the population is estimated at about 100 mice per acre.

On small ranches the control of field mice requires little time and is usually a minor expense. On some larger ranches, however, where the acreage is great and where the infestation is so severe that the fields must be poisoned several times a year, control can be very costly. On one ranch, the expense of poisoning field mice was from two to four dollars per acre annually, or at times more than $2,400 for 600 acres of alfalfa requiring control of mice.

The study plots discussed here were in fields and pastures rather heavily infested with mice, and were typical of those ordinarily poisoned by ranchers. Four of the tests were made in alfalfa fields in the Delta area (Sacramento County), and two were conducted in a small irrigated pasture in the Sutter Basin (Sutter County). The poison-bait mixture is standard throughout much of the United States. The bait was distributed by hand with most of the material being thrown in burrow entrances; the labor was farm help, or farm help and the writer.

POSSIBLE ALTERNATE METHODS OF BAIT DISTRIBUTION

For more rapid and economical distribution of poisoned baits, Eadie (*op. cit.*) and Hayne (*op. cit.*) have suggested hand-operated mechanical seeders and airplanes. In some parts of the United States, Europe and Soviet Union, tractor-drawn or horse-drawn bait spreaders are used. Airplanes would be the most rapid but have disadvantages. The ranch labor used to distribute poisoned bait is hired on a year-around basis; and the employment of an airplane would be an additional expense, not a saving. Moreover, an airplane moves so fast that no adjustment can be made for varying intensities of infestations of mice; some areas would receive insufficient poison and other areas too much.

The hand-operated mechanical seeder would appear to be best suited to California conditions. The use of one type of seed distributor has been described by Eadie (*op. cit.*). Working in New York orchards, Eadie used a seeder that distributed bait in rows, close to the ground; and the poison (2 per cent zinc phosphide on corn) was placed in parallel lines on each side of a row of trees. The rows of bait were from 25 to 35 feet apart; this was considered sufficient since mice will wander that far in their daily foraging. The reductions of mice were from 75 to 80 per cent in a series of trials; this does not compare at all favorably with the results obtained in tests with hand-distributed baits in the Sacramento Valley and Delta area. However, the technique proposed by Eadie was considerably faster and therefore cheaper; he was able to distribute bait on 4 acres in one hour, approximately three times the area covered by one man in one hour in this study. Eadie's method has been tried and checked by Hayne (1950), who obtained similar results.

The relatively low kill (75 to 80 per cent) obtained in the New York State trials could have been caused by the restricted distribution of the bait, although in a letter (18 February 1957) Dr. Eadie has suggested that it was caused by a delay in the post-poisoning census. Considerably heavier kills might result if the bait were distributed in wide swaths instead of in narrow parallel rows, for certainly this would increase the chances of mice eating the bait quickly. Mechanical, hand-operated seeders, of the type that can be strapped to the chest, would accomplish this.

SUMMARY

Studies were made of six trials of poisoning field mice (*Microtus californicus*) using one per cent zinc phosphide on rolled barley. Mice were censused on 1-acre square plots immediately before and after poisoning, populations being estimated from data obtained by live trapping for five days in each instance. In four trials the mean reduction was found to be 95.5 ± 1.3 per cent. In two trials, where the post-poisoning census was made ten days after poisoning, the mean reduction was only 82.4 ± 2.2 per cent; here the difference was caused by an invasion of mice into the poisoned plots. It is suggested that a more rapid distribution of the bait will increase the effectiveness and reduce the cost of poisoning operations. Mechanical seed distributors are now being tested to accomplish this.

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NON-UNISEXUAL BROODS IN THE MOURNING DOVE[1]

Wallace G. Macgregor

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Kossack and Hanson (1953) reported on 21 broods of mourning doves (*Zenaidura macroura*) reared in captivity. Of the 21 broods recorded, 13 were composed of two males each, and 8 contained two females each. While they brought out that 21 such unisexual broods were not likely to be encountered purely on the basis of chance, they stressed the advisability of their finding being substantiated by other observers.

The California Department of Fish and Game, through its Upland Game Investigations Project, has been carrying on a study of the mourning dove in this state. In conjunction with this study, 11 broods were taken from their nests and reared in captivity to provide additional information on the rate of molt as an age indicator and to check on the unisexual broods.

The squabs were from 7 to 10 days old when taken from the nests. They were immediately banded with the standard Fish and Wildlife Service serially numbered alumnium bands. Any birds that died in the course of the experiment were dissected and sexed by macroscopic examination of the reproductive organs and then placed in a preservative. At the end of the experiment, the sex of all birds was determined by internal examination of the reproductive organs. I am indebted to Dr. Ursula Abbott of the Poultry Husbandry Department of the University of California at Davis for independently checking the sex of all the birds.

In the 11 broods checked, six contained one male and one female each, three contained two males each, and two contained two females each. This approximates the expected 1:2:1 ratio as is found in pigeons (Levi, 1941). Although the number of broods checked was small, the results show that mourning dove broods are not regularly unisexual.

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Received for publication July 26, 1957.

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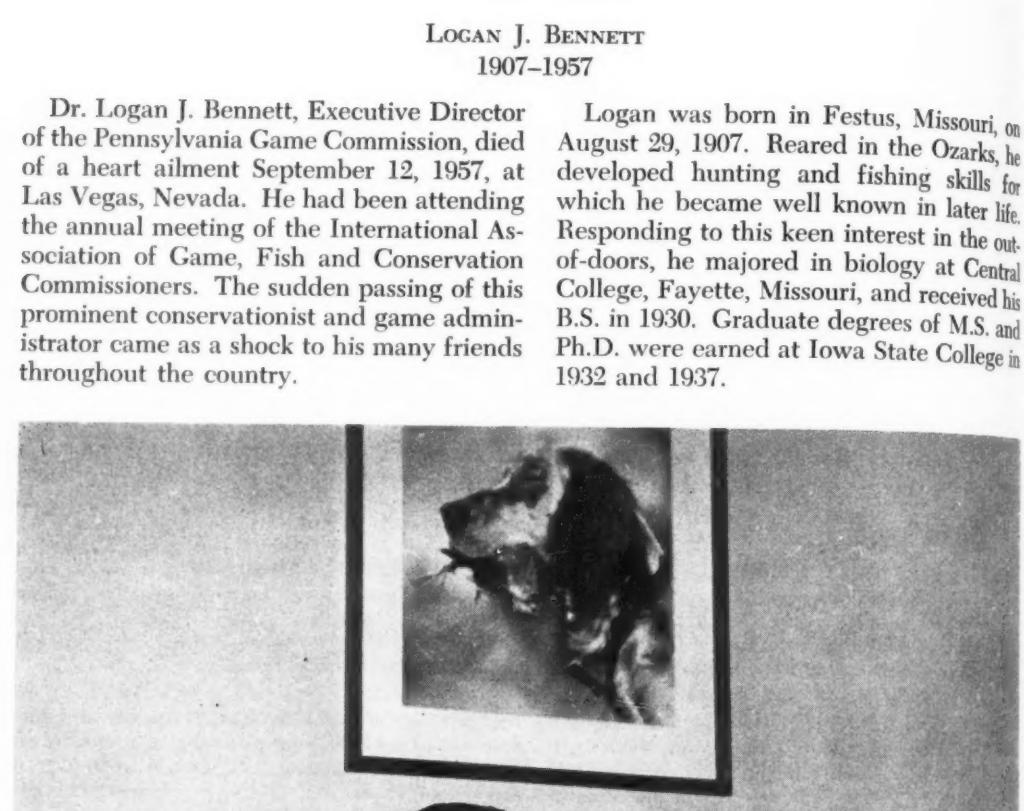
OBITUARIES

Logan J. Bennett
1907–1957

Dr. Logan J. Bennett, Executive Director of the Pennsylvania Game Commission, died of a heart ailment September 12, 1957, at Las Vegas, Nevada. He had been attending the annual meeting of the International Association of Game, Fish and Conservation Commissioners. The sudden passing of this prominent conservationist and game administrator came as a shock to his many friends throughout the country.

Logan was born in Festus, Missouri, on August 29, 1907. Reared in the Ozarks, he developed hunting and fishing skills for which he became well known in later life. Responding to this keen interest in the out-of-doors, he majored in biology at Central College, Fayette, Missouri, and received his B.S. in 1930. Graduate degrees of M.S. and Ph.D. were earned at Iowa State College in 1932 and 1937.



Dr. Logan J. Bennett, eleventh president of the Wildlife Society.
(Photographed February 15, 1957 by D. L. Batcheler, Pennsylvania Game Commission.)

He began his professional career as Game Technician for the Iowa State Conservation Commission in 1934. In July 1935, he joined the Bureau of Biological Survey as Junior Refuge Manager of the Trempealeau National Wildlife Refuge in Wisconsin. In September of that year, he was appointed Leader of the newly organized Iowa Cooperative Wildlife Research Unit at Ames. On March 1, 1938, he transferred to State College, Pennsylvania, where he organized and served as the first leader of the Pennsylvania Cooperative Wildlife Research Unit.

During World War II, Logan served from July 15, 1943, to December 16, 1945, as officer in charge of a malaria-control unit in the South Pacific. He held the rank of Lieutenant (s.g.) with the U.S. Navy.

Following military service, he returned to his position as Leader of the Pennsylvania Cooperative Wildlife Research Unit and on December 1, 1947, he was promoted to the post of Biologist in Charge of the Cooperative Unit Program for the U.S. Fish and Wildlife Service. On September 27, 1948, he became Chief of the Service's Branch of Wildlife Research, a position he held until joining the Pennsylvania Game Commission as Executive Director on October 1, 1953.

Author of numerous popular and technical articles, Logan's best-known publication probably is "The Blue-Winged Teal—Its Ecology and Management." Among bird-dog fanciers, he is well known for his book "Training Grouse and Woodcock Dogs."

As charter member of the Wildlife Society, Logan contributed generously of his time and talents in building the organization. He served as Secretary in 1942, 1943 and 1946, and was president in 1947. He played a prominent role in the incorporation of the Society in 1948. His interests were broad, and he held membership in a number of other organizations, including the American Ornithologists' Union, the American Society of Mammalogists, the National Rifle Association, and the Outdoor Writers Association.

Evidence of the high esteem in which he was held by sportsmen around the country came to Logan on June 6 of this year. On that date, he received the Winchester Award of Outdoorsman of the Year for 1956, a recognition that resulted from a nation-wide poll of 1,250 outdoor columnists and free-lance writers from every state. In May of this year he was chosen by the Under Secretary of the Navy to serve on the Navy's Advisory Group on Wildlife and Natural Resources.

Revered by many as a staunch friend, Logan was known to all as a skilled and considerate sportsman, a dedicated, able and outspoken conservationist.

He is survived by his wife, Eleanor, of Mechanicsburg, Pa., a son, Logan J., Jr., who is a student at Central College, Fayette, Missouri, a daughter, Mrs. James H. Westergaard of Chattanooga, Tennessee, and a granddaughter, Kimberly Ann Westergaard.

—J. P. LINDUSKA.

LEE WEIGHT ARNOLD
1914–1956

Lee W. Arnold, a life member of The Wildlife Society, passed away at a Veteran's Administration hospital in Los Angeles on February 12, 1956. He had been a patient for a service-connected disability for about three years.

That Lee Arnold's professional career should have been one closely associated with wildlife was ordained by the environment in which his early years were spent. Born in San Diego, California, on October 19, 1914, Lee lived in the immediate vicinity of the local zoological park and museum, and some of his early jobs were at these institutions. His subsequent ability as an outdoorsman, no doubt, had its foundation in the training received in acquiring the status of an Eagle Scout and leader of a Boy Scout troop. On family property in the foothills near Ramona in eastern San Diego County, Lee Arnold spent many week ends and vacations, and it was here where he first trapped animals and learned the rudiments of taxidermy. The seashore, not far away,

gave him an early insight into the mysteries of marine life.

Lee Arnold's higher education began at San Diego State College in 1933, followed by a year at the University of California in 1936, where he obtained a bachelor's degree in zoology. A master's degree, in which he majored in economic zoology, was acquired at the University of Arizona during the years 1938–40.

To assist in obtaining his education, Arnold engaged in curatorial work (San Diego Natural History Museum), collecting of natural history specimens (University of California), and teaching (University of Arizona).

During 1941 and 1942 Arnold was employed as a field technician by the Arizona Game and Fish Commission and served that agency in connection with Pittman-Robertson projects. He was the author of a hundred-page document, *The Western White-winged Dove in Arizona,* published by the commission in 1943.

A period of military duty then interrupted Arnold's career in the natural sciences. He entered the Navy as an ensign in November 1942, and served with both the Atlantic and Pacific fleets as communications officer on a minesweeper. Much time was spent in the Aleutian area. While he was being transferred to a base in Hawaii, his plane went down midway between San Francisco and its destination. He received injuries that required hospitalization, first in Hawaii and later in California. During his service in the Navy, Arnold attained the rank of Lieutenant (j.g.).

In 1947 Arnold was appointed as biologist with the U.S. Fish and Wildlife Service and was assigned to the Wildlife Research Laboratory at Denver, Colorado. Here he assembled information on the reaction of birds and mammals to electric and ultrasonic vibrations and conducted experiments in this field in cooperation with the Bureau of Mines Laboratory in Salt Lake City. However, his major contribution while with the Denver Laboratory was the completion of a field study of the economics of the golden eagle, and the preparation of a report thereon, which appeared as Circular 27 of the U.S. Fish and Wildlife Service in 1949.

As frequently happens in governmental organizations, the abilities of outstanding employees become known beyond the limits of their own respective unit. It took only nine months for this to take place with Lee Arnold. He then was offered and accepted a more lucrative position at the Albuquerque regional office of the U.S. Fish and Wildlife Service, where he served as regional inspector of the Division of Federal Aid to Wildlife. The condition of his health and the exacting nature of his job compelled him, in 1951, to transfer to the Division of Refuges where he could spend more time in the out-of-doors. He resigned from the U.S. Fish and Wildlife Service in November 1952.

Lee Arnold's personality was characterized by originality of thinking. Even during his relatively brief assignment at the Denver Laboratory, this trait became obvious to all his associates. As director of the laboratory at that time, I sensed his keenly analytical mind and soon realized that Lee could ask more unanswerable and challenging questions than any other staff member. He brought to us, individually and to the programs of research, a wealth of original thinking. His refreshing approach is still having its effect on work being done there.

Arnold's sterling qualities were apparent to associates even in the formative stages of his life. While at the University at Tucson he was well liked by both fellow students and members of the faculty. This attribute fitted perfectly into the tutoring job he held. There is every reason to believe that many a player on the varsity team owed as much to Lee Arnold as to the football coach for his being allowed on the field. The high regard in which the faculty held Lee Arnold can best be appreciated by a remark once made to the writer of this memorial by the late Dr. Vorhies: "Had Lee not entered the Fish and Wildlife Service, but had decided to make teaching his profession, I was prepared to groom him as my successor."

Arnold made friends easily both within and outside of his chosen profession, and it mattered not whether the occasion was a pheasant hunt, a hike to a mountain top, a "bull session" at the laboratory, or a modest game of penny-ante at a friend's home. Although he could never be identified as the "life of the party," Lee Arnold always made our gatherings richer.

Lee Arnold was buried in the family plot in the Mount Hope Cemetery in San Diego. His wife, Elizabeth (nee Standring), and four children, James Robert 11, John Charles 10, Elizabeth Anne 8 and Talitha 4, make their home in Phoenix, Arizona. Lee Arnold is survived also by his mother and father, who still live in San Diego; a brother, Gilbert C. Arnold in New Orleans; and two sisters, Mrs. R. G. Muench of San Diego and Mrs. M. Breckenridge of Chico, California.

I am greatly indebted to Mrs. Arnold for much of the information regarding Lee's early life and his military service.—E. R. KALMBACH.

LAWRENCE E. HICKS
1905–1957

Lawrence Emerson Hicks, charter and life member of The Wildlife Society died in White Cross Hospital, Columbus, Ohio on January 20, 1957 following a cerebral hemorrhage. A tireless field biologist, he took part in six Christmas bird counts in a short period just prior to his death. His defiance of the elements and overconfidence in his physical capacity were typical of the way he lived.

Lawrence was born at Fredericktown, Ohio on October 22, 1905. As a boy he had strong leanings toward biology. He was a Lone Scout and contributed nature articles to the *Lone Scout* magazine. He attended Otterbein College at Westerville and graduated in 1928. Entering Ohio State University, he served as graduate assistant and instructor in the Botany Department, where he engaged in research on the duckweeds and the original vegetation of Ashtabula County. This work gained him the M.A. and Ph.D. degrees. During the summers Lawrence worked as a field agent for the Bureau of Plant Industry, U.S.D.A., as a game ecologist for the Ohio Division of Conservation, and as a professor at the Ohio Conservation Laboratory. He was a field ecologist and instructor for the New York State Museum at the Allegany School of Natural History in the summer of 1931 and a forester and game conservationist for the U.S. Soil Conservation Service in the Muskingum Valley from 1934 to 1936. In 1938 he was U.S. delegate to the International Ornithological Congress at Rouen, France.

When the Cooperative Wildlife Research Unit was established at Ohio State University in 1936, he became its first director. Starting with two or three graduate students and headquartered in a small cubicle in the basement of the Veterinary Clinic building on the Ohio State campus, the Unit quickly became a center of feverish activity in wildlife research and attained national recognition for its work on the ring-necked pheasant. An enthusiastic leader, Lawrence set the pace for his students in grueling and exacting field work. Looking back on those years, when this biographer, too, was a student of Hicks's, it seemed like a race against time. No fragment of information pertaining to Ohio's wildlife resources was thrown away. Soon the tiny room in the Veterinary Clinic building became so filled with file boxes, books, and specimens that there was no room for the students to work. Hicks then conceived the idea of field stations, and one by one the graduate students left the campus to take up headquarters on or near their study areas. Lawrence became a roaming biologist and spent most of his time traveling from one study area to another, pausing frequently enroute to engage in his passion for collecting birds and plants. He stated many times that he had carried on field work in every township in Ohio, and it is doubtful if anyone can dispute this.

While in the field he seldom took time out to stop at a restaurant, relax and enjoy a

good meal. His students will recall the mud-spattered car with its rear seat piled with crackers, cheese, bologna, candy bars, melons, and other "ready-made" foods, which he munched while driving. As often as not in summer there would be a rapidly melting block of ice on the floor mat, partially concealed by blankets, shotguns, binoculars, and other paraphernalia. On these trips he loved to sing and often engaged in "close harmony" with whomever he might be riding. Although he was a strenuous field worker with seemingly an endless supply of energy, there were moments when he took time out to play. He developed considerable prowess in wrestling while in college and would often challenge a whole group of wildlife students to wrestle with him, or coax them into going swimming. He developed, in this way, a companionship with his students that is rare among college professors. As a teacher, he was at his best in the field, where ecological concepts were simply explained, using plant and animal materials that were always at hand.

During World War II his "boys" were kept in touch with each other and with the activities of the Research Unit through a monthly newsletter which he sent to them all over the world.

Whatever may have been his shortcomings, Lawrence Hicks gained recognition as a brilliant field biologist and ecologist. He had a keen perception of wildlife conservation problems, which developed, no doubt, from his excellent training in botany, field experience with birds and plants, wide acquaintance with professional wildlife men, and an up-to-the-minute knowledge of the literature. *The Ring-necked Pheasant and Its Management in North America*, to which he contributed the principal chapter, won the Wildlife Society Publication Award in 1945.

After 1945, when he left the Wildlife Research Unit at Ohio State, Lawrence was occupied with beekeeping, and at the time of his death was owner and operator of the Buckeye Apiaries, with 2,000 hives located in eight counties. While making a comfortable living as an apiarist, Lawrence also found time to collect rare plants and birds. His study collection of bird skins, which was willed to the Ohio State Museum, contains about 2,000 specimens and he has contributed thousands of sheets of mounted plants to the Ohio State Herbarium.

Besides his affiliation with The Wildlife Society, Lawrence Hicks was a fellow and former secretary of the American Ornithologists' Union, a member and former president of the Wilson Ornithological Society, former president of the Wheaton Club, and an active member of the Brooks Bird Club of Wheeling, West Virginia. He was also a member of Sigma Xi and Gamma Alpha, scientific honorary societies. In recent years he took up another hobby, collecting Indian relics, and joined the Ohio Archaeological Society, soon becoming its president.

He is survived by his wife, the former Thyra BeVier, a daughter, Mrs. Clement A. F. Hastie of Cambridge, Massachusetts, a son, Thomas Edward Deam Hicks, a brother, Morris, and both parents.—FLOYD B. CHAPMAN.

ERRATA

In Vol. 21, page 65, line 24, *for* 0.07, *read* 0.7.

In Vol. 21, page 429, an entire category was confusingly presented under "Poultry" in Table 4. This should have read:

POULTRY	(5.2)	(1.6)
Chicken	4.3	1.2
Turkey	0.3	0.3
Duck	0.6	0.1
LIVESTOCK	(2.8)	(1.2)
Calf	0.9	0.6
Pig	1.5	0.4
Lamb	0.3	0.2

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